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WAR DEPARTMENT

TECHNICAL MANUAL

HAND, MEASURING, AND POWER TOOLS

May 26, 1941

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WAR DEPARTMENT,
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HAND, MEASURING, AND POWER TOOLS

Prepared under direction of
The Quartermaster General

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SECTION I

GENERAL

1. **Employment.**—*a. General.*—(1) Tools are the machinist's and mechanic's best friend. Without them a mechanic is as helpless as he would be without his eyes. In fact, he would be more helpless, for a blind mechanic skilled in the use of good tools can do more than the most expert mechanic without tools. Regardless of the type of job to be done, a mechanic must have, choose, and use the correct tools in order to do the work quickly, properly, and accurately. Without the proper tools and the knowledge of how to use them, a mechanic wastes time, cuts efficiency, and may injure himself. This text explains the specific purposes, correct use, and proper care of the common tools of the motor vehicle mechanic.

(2) Mechanics' and machinists' tools are carefully made and demand particular care if they are to work and last as the manufacturer intended. No mechanic can do satisfactory work with poorly kept tools. The mechanic should have his own tool box and keep his tools in it when not using them. Each tool should be given a place and kept there. If possible, the box should be locked to prevent theft. A common type of tool box is shown in figure 1. Tools are cleaned before they are put away. Those which may not be used again for some time are oiled to prevent rust. When working, a mechanic keeps his tools within easy reach and where they cannot fall on the floor. Tools are never placed on the finished parts of a machine, such

as the ways of a lathe. Damaged tools are never used. A battered steel rule is hard to read and may spoil a job. A gage strained out of shape will give an inaccurate measurement. A battered screw driver may slip and spoil the screw slot or cause a painful injury.

b. Classes of tools.—The mechanics' and machinists' tools treated in this manual are classified as hand tools, measuring tools, and power tools. Each type has its special characteristics and purposes and should be used accordingly.

(1) *Hand tools.*—Hand tools are usually small and portable and are used with the hands to perform mechanical operations. Screw drivers, hammers, pliers, vises, and so on, are included in this class.

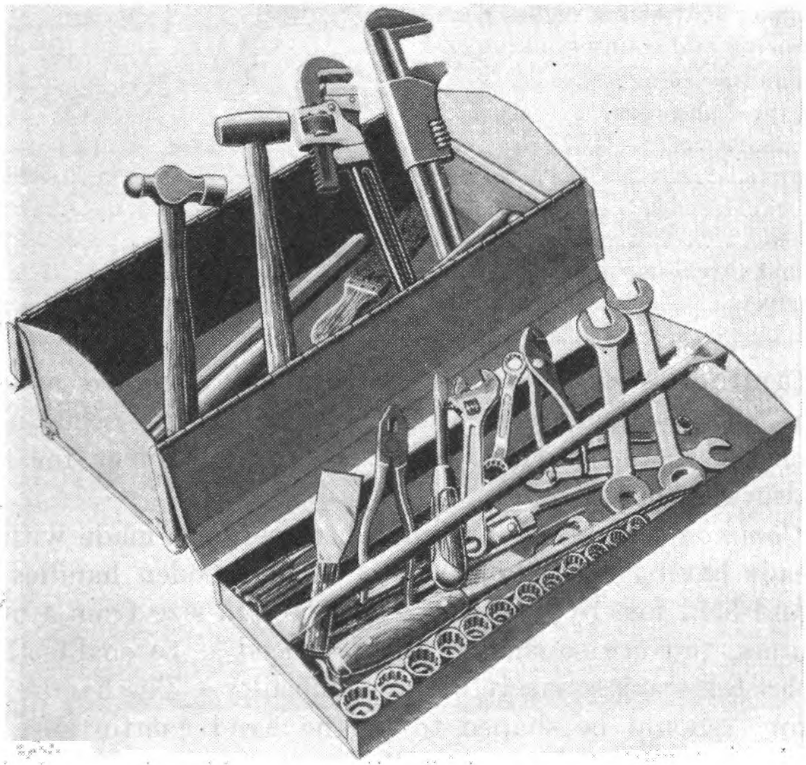

FIGURE 1.—Mechanic's tool box with tray removed.

(2) *Measuring tools.*—Measuring tools are used for measuring work accurately. Rules, dividers, micrometer calipers, and so on, are included in this class.

(3) *Power tools.*—Power tools are operated entirely or partly by power, such as electricity or compressed air, in order to make an operation easier or faster, or more accurate. Electric drills, air hammers, valve refacers, and so on, are included in this class.

SECTION II

USE AND CARE OF HAND TOOLS

2. Hammers—*a. Types*.—Hammers are classified as common hammers, soft hammers, and sledges. Each has its special uses, and the mechanic should learn to select the right hammer for the particular work in hand.

(1) *Common hammers*.—Common hammers are made with forged steel heads having eyes (holes) into which wooden handles are inserted and held fast by wedges. They vary in size from 4 ounces to 2½ pounds, and are so shaped and balanced as to enable the operator to hit the mark squarely without difficulty. The handle, usually of hickory, should be shaped to fit the hand comfortably and fit *tightly* into the eye. Figure 2 illustrates the hammers ordinarily used in motor-vehicle maintenance work. The ball-peen hammer is used most frequently by mechanics. The peen of this hammer is used for heading rivets and similar peening or drawing operations; the cross-peen hammer is used for spreading or drawing out metal at right angles to the handle; the straight-peen hammer performs the same operation in line with the handle. The claw hammer is used by carpenters for driving and pulling nails.

(2) *Soft hammers*.—Hammers with heads made of soft material, such as lead, copper, babbitt, or rawhide, are called soft hammers.

Two common types are shown in figure 2. They are used generally for any operation where a steel hammer might mar or injure the work.

(3) *Sledges.*—Sledges (fig. 3) are hammers weighing from 4 to 20 pounds and having handles from 30 to 36 inches long. They should be used only on work requiring an exceptionally heavy blow.

b. Use and care.—The hammer should be held near the end of the handle with its face parallel to the work. A grip just tight enough

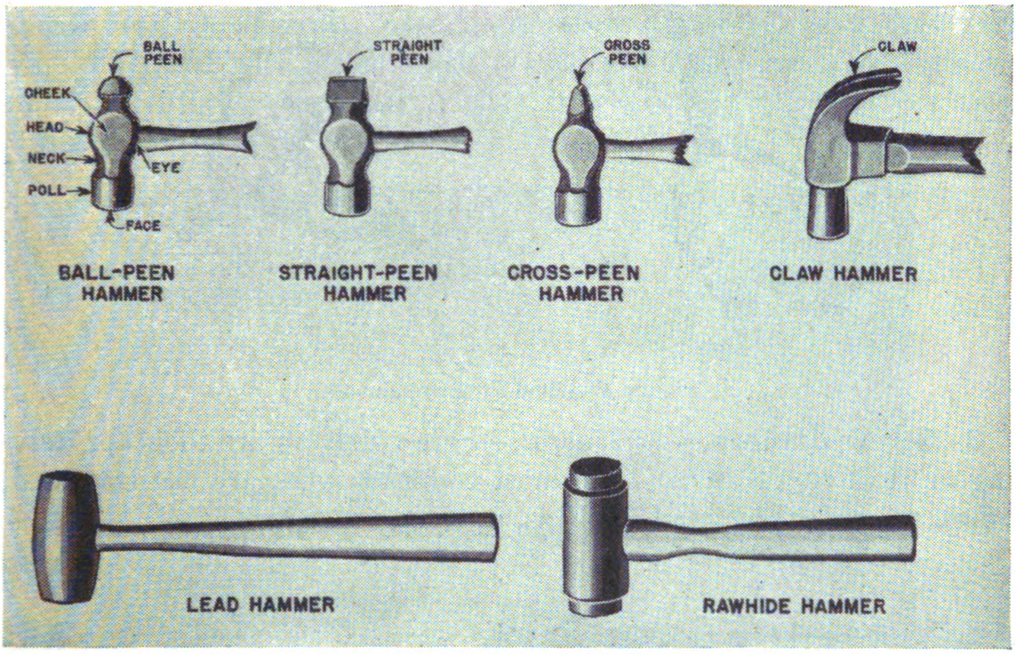

FIGURE 2.—Types of hammers.

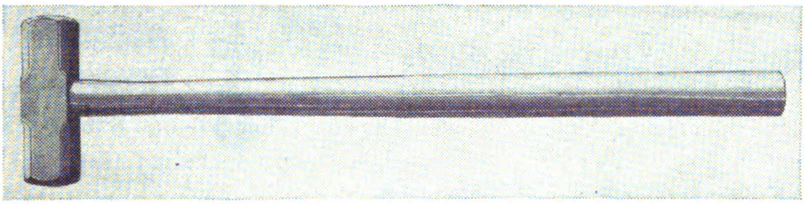

FIGURE 3.—Sledge.

to control the blow is best. Raise the arm straightaway from the object to be struck and then bring the hammer down on it with a quick, sharp motion. Figure 4 shows the right way to use a hammer. Do not hold the handle close to the hammer head and *never* use it as a pry or scraper.

c. Safety precautions.—Probably most accidents with hammers are caused by a loose hammer head. A sweaty palm or an oily or greasy

handle will let the hammer slip out of the hand, and any oil or grease on the hammer face may cause the face to slip off the work and give a painful bruise.

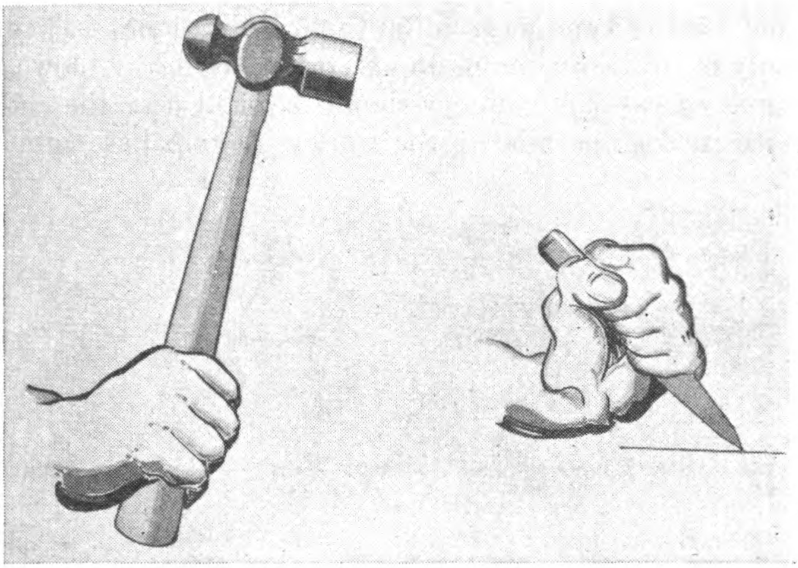

FIGURE 4.—How to hold hammer.

3. Screw drivers.—*a. General.*—Screw drivers are tools for driving or removing screws. The most common types are the standard, offset, spiral ratchet, and Phillips, as shown in figure 5.

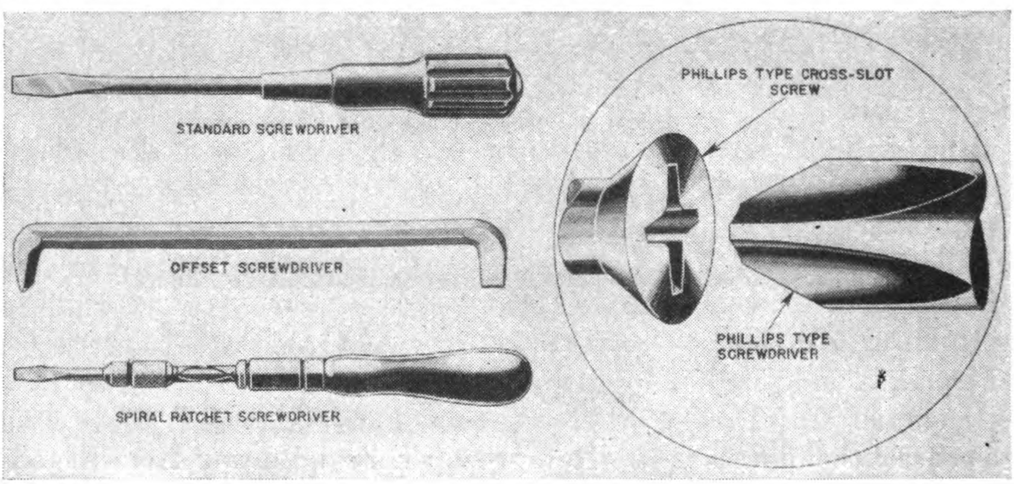

FIGURE 5.—Types of screw drivers.

(1) The *standard screw driver* is suitable for most ordinary work. The blade (or end) must have sharp corners and fit the slot in the screw closely; otherwise it is likely to slip and damage the slot. It is important that any screw driver be held firmly against the screw to prevent it from slipping and injuring the worker or scratching the work.

(2) The *offset screw driver* makes work possible in tight corners where the standard straight type will not enter.

(3) The *spiral ratchet screw driver* is used to drive or remove small machine screws rapidly.

(4) The *Phillips type screw driver* is made with a specially shaped blade to fit Phillips type cross-slot screws. Figure 5 shows clearly the way the tool works.

b. Correct use and safety precautions.—(1) Keep the point of the screw driver properly ground, as shown in figure 6. The point should be free of grease or oil. A screw driver of the proper size should be used with a point that fits the slot in the screw; otherwise, the point of the screw driver may break or the screw driver may slip and mutilate the screw slot or the work.

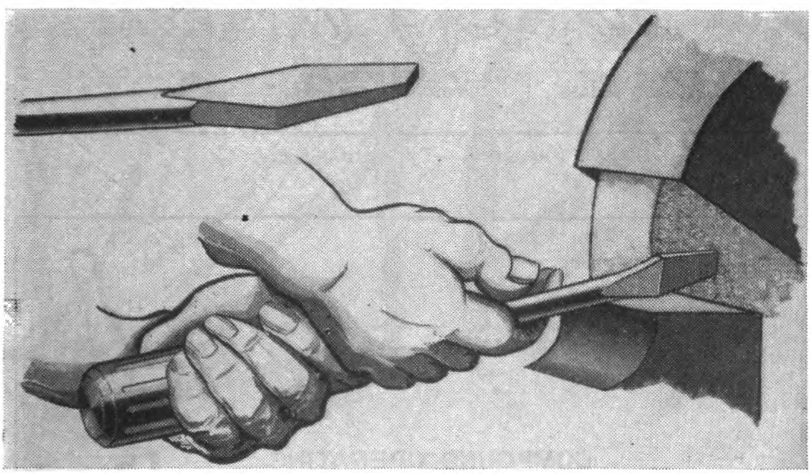

FIGURE 6.—Grinding a screw driver.

(2) It is dangerous to hold work in the hand while tightening or loosening a screw. If the blade slips, it can give a bad cut. It is better to put the work in a vise or on a solid surface that will bear the pressure of the driver.

(3) It is bad practice to—

(*a*) Use the screw driver as a chisel.

(*b*) Strike the handle with a hammer.

(*c*) Use the screw driver for prying or as a tire tool.

4. Shears, pliers, and nippers.—*a. General.*—Shears, pliers, and nippers are tools used to hold, turn, cut, shape, or bend light work by hand.

(1) *Shears.*—Shears are used for cutting sheet metal of various kinds and thicknesses. Figure 7 shows several commonly used types. Straight blade tinners' shears are used for making straight cuts. Shears with curved blades are convenient for making curved cuts.

Scroll pivoter snips turn easily and follow an irregular line readily. Bench shears are used for cutting metal of 16 gage and lighter. Bolt cutters are used for cutting bolts or small bars of metal. In selecting bolt cutters, use one with cutting jaws that will open wide enough to accomodate the work. Figure 8 shows a combination shears and

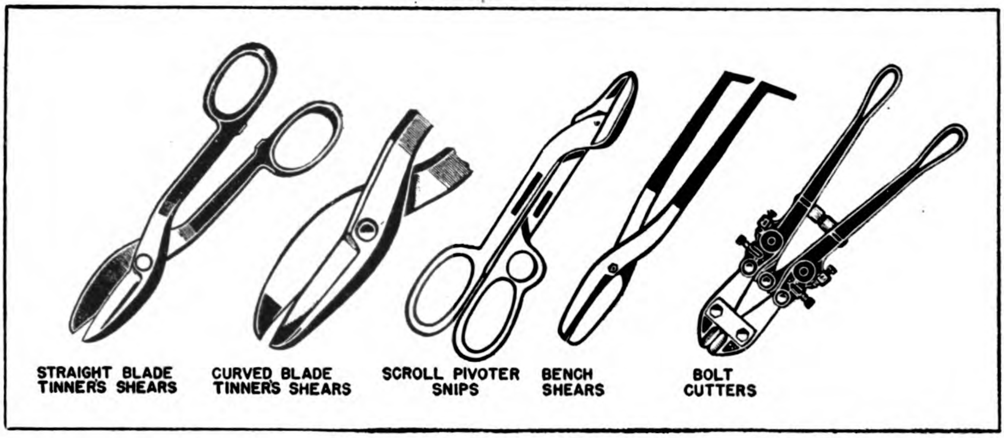

FIGURE 7.—Types of shears.

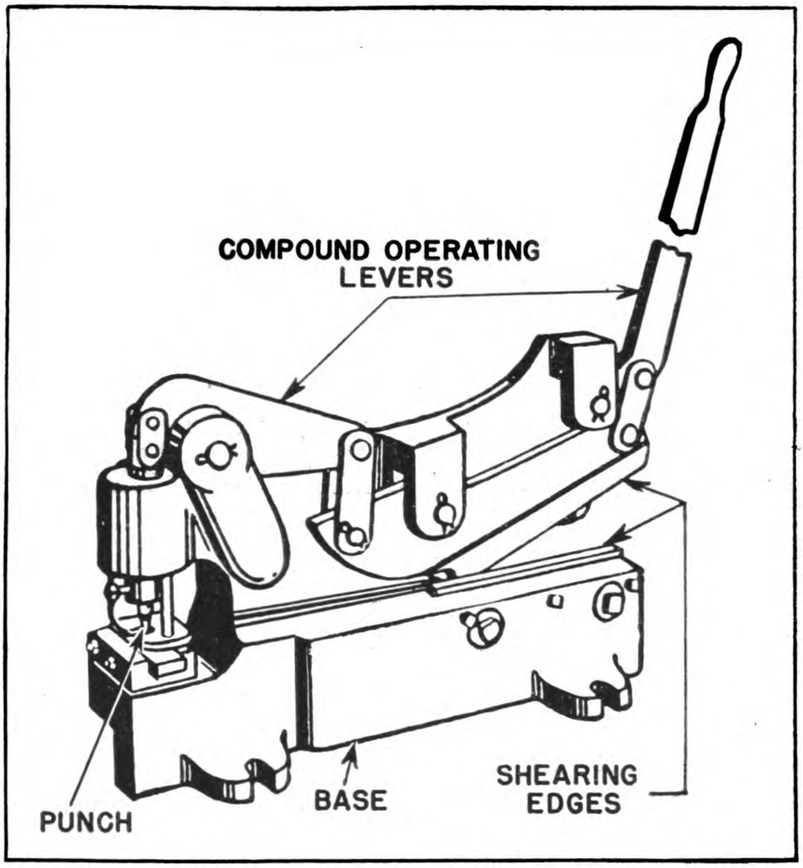

FIGURE 8.—Combination shears and punch.

punch to be mounted on the bench for cutting bars or for cutting and punching holes in sheet metal. Bolt cutters and punches usually have compounded operating handles in order to increase the leverage.

(2) *Pliers.*—Figure 9 shows the commonly used types of pliers. Side-cutting pliers are used principally for holding and bending thin material, or for cutting wire. Adjustable combination pliers are general purpose tools used for holding flat or round stock and for cutting wire. The various lengths and shapes of flatnose, roundnose, and half-roundnose pliers make it possible to bend or form metal into a variety of shapes or to work in close spaces. Many special

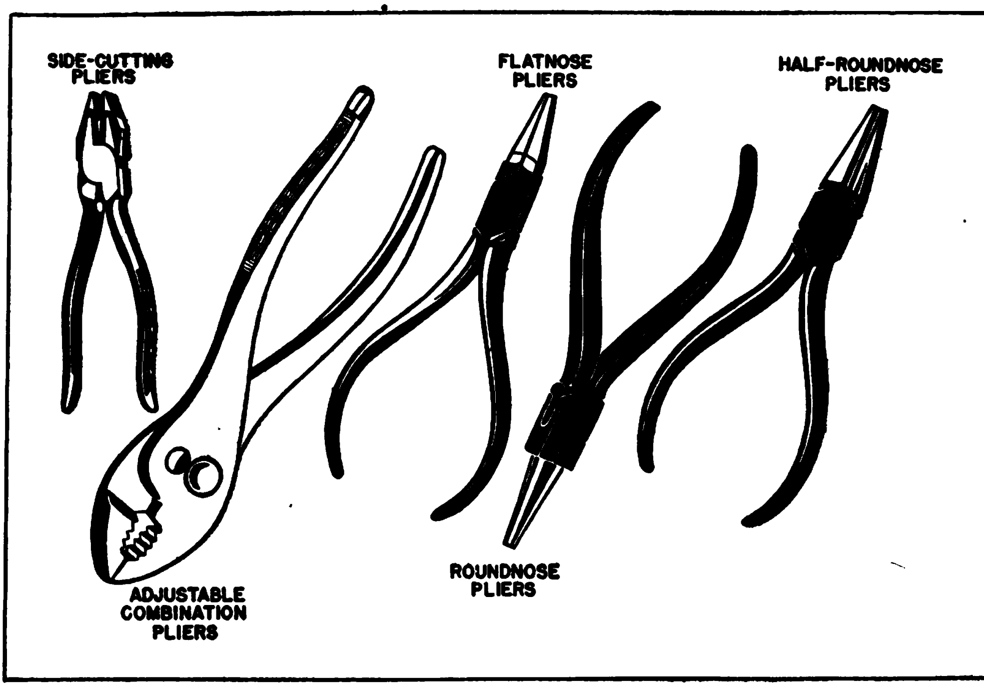

FIGURE 9.—Types of pliers.

purpose pliers are available for doing specific jobs, such as tire chain repair pliers and brake spring pliers.

(3) *Nippers.*—(*a*) Nippers (fig. 10) are used strictly as cutting tools for wire, light metal bars, bolts, etc., especially for cutting them off flush with a surface. They exert more force than pliers and should never be used as holding tools.

(*b*) Diagonal cutters are convenient for cutting off small stock, such as cotter keys, in inaccessible places.

b. Use and safety precautions.—Shears, pliers, and nippers are made in a wide range of sizes to avoid overstraining and perhaps breaking a tool. Judgment should be used in selecting one heavy enough for the job. It is bad practice to use pliers instead of

wrenches to tighten or loosen nuts; the pliers are likely to damage the "flats" of the nut. If dirty, greasy, or oily tools are used, they can slip and skin knuckles or cut scratches in finished work.

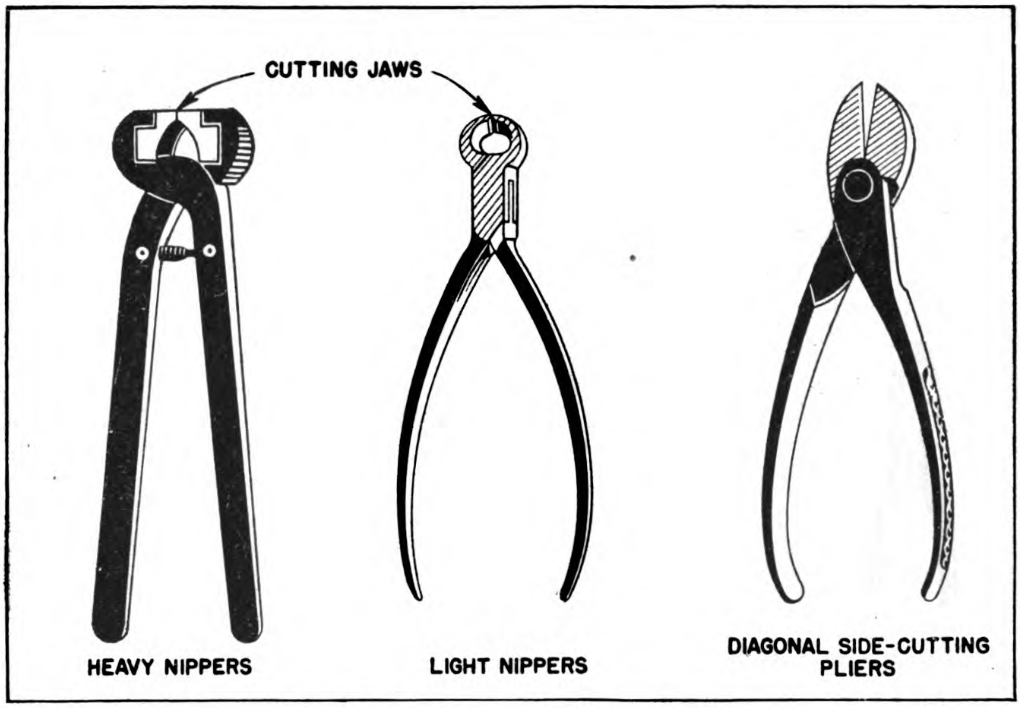

FIGURE 10.—Nippers.

5. Wrenches.—*a. General.*—Wrenches are tools for tightening or removing nuts, bolt heads, or cap screws; or for gripping round material such as pipe, studs, and round rod. They are generally classified as adjustable wrenches, socket wrenches, open-end wrenches, box wrenches, and pipe wrenches, as shown in figure 11.

(1) *Adjustable wrenches.*—Adjustable wrenches are made so their jaws can be opened or closed to fit the flats of the nut or bolt head to be turned; the monkey wrench and the adjustable open-end wrench are common types. As a rule, adjustable wrenches are suitable for heavy duty in places easy to reach.

(2) *Socket wrenches.*—Socket wrenches are frequently used in automotive work, where it is often necessary to operate in close or inaccessible places, because a ratchet handle which requires only a very short swing can be used on them. The sockets are supplied in sets to fit standard-sized nuts and are readily fitted into or removed from the handle. The nut can be completely tightened without removing the wrench from the work.

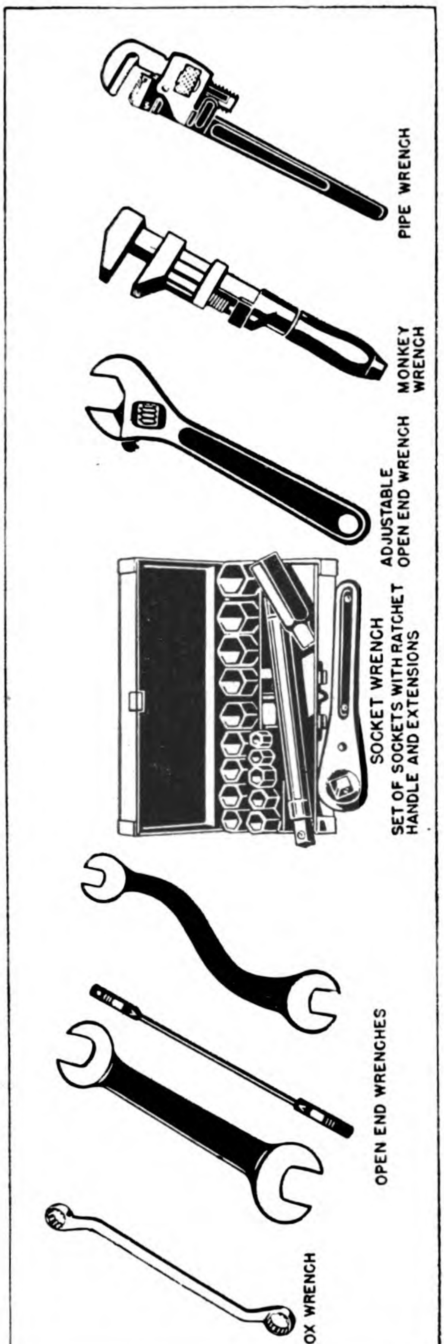

FIGURE 11.—Types of wrenches.

(3) *Box wrenches.*—Box wrenches are used for general purpose work; they are well suited to operation in close quarters, since their heads are small and as little as a twelfth of a turn can be taken each time the wrench is shifted.

(4) *Open-end wrenches.*—Open-end wrenches fit standard-sized nuts and are light, strong, and convenient for working in a limited space. Because the jaws are set at an angle (usually 15° or 90°), it is easy to increase the swing of the handle by turning the wrench over. Like socket wrenches, they are often used in automotive work. Sets of midget open-end wrenches are available for ignition and electrical work.

(5) *Pipe wrenches.*—Pipe (or Stillson) wrenches are used for turning pipe, round rod, or smooth fittings which do not offer a gripping surface for other types of wrenches. However, the bite of their jaws mars the work. They should never be used on nuts or bolts.

(6) *Stud wrenches.*—Stud wrenches (fig. 12) are used with a socket wrench handle for removing or setting studs. A knurled

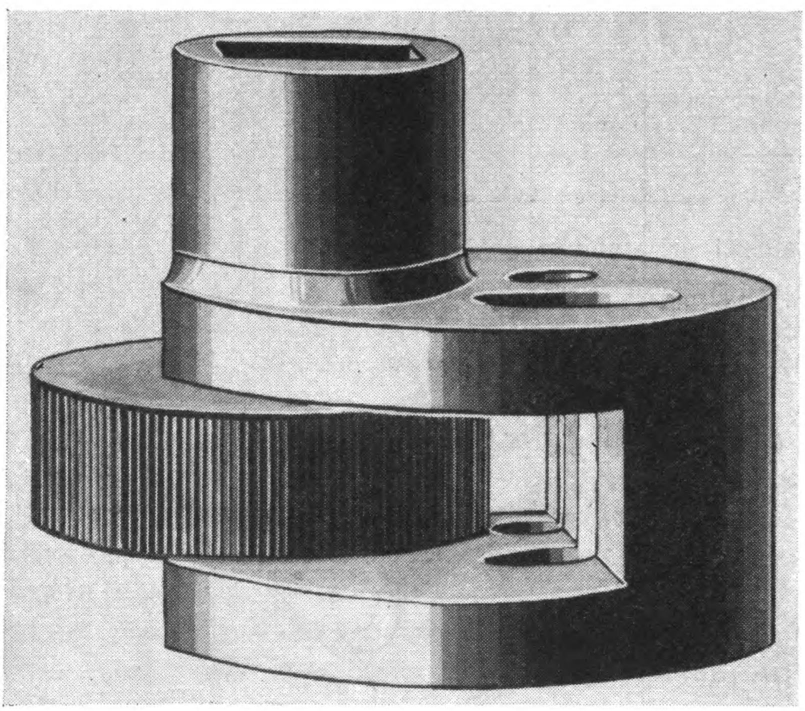

FIGURE 12.—Stud wrench.

cam bears against the stud, gripping it forcefully so it can be turned in or out.

b. Use and care of wrenches.—In using the adjustable open-end wrench (fig. 13) adjust it so the jaws slip easily over the nut with

no great amount of "shake" or "backlash." A loose wrench is liable to slip or break and possibly injure the worker. The pull on the wrench should always be in the direction shown by the arrow in figure 13. In this illustration, for example, if the wrench were to be turned in the direction opposite to that indicated, it should first be turned over. When using the monkey wrench, turn the jaws up snugly against the nut; in selecting a socket, box, or open-end wrench, use one that fits closely on the nut, but not so tightly that it is hard to remove. To get maximum leverage when using any wrench, always pull at right angles to the wrench and to the center line of the bolt.

c. Setting up nut.—The best way to tighten a nut is to turn it until the wrench has a firm, solid "feel." Then give the wrench a sharp jerk. This will set the nut up to its final position without twisting off the bolt or stripping the threads in the nut. This "feel"

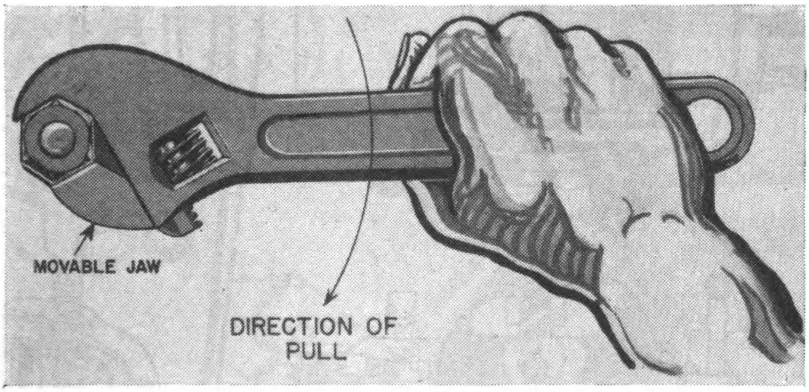

FIGURE 13.—Use of adjustable open-end wrench.

comes only with experience, and one should practice and learn it as soon as possible.

d. Safety precautions.—When using any kind of wrench, take the following precautions:

(1) Be sure the wrench, the outside of the nut, and the hand are all free of oil or grease. Be sure the wrench fits the nut to prevent slipping and falling. An improperly fitting wrench not only rounds off the corners of the nut or bolt head but also places an undue strain on the wrench jaws.

(2) If an adjustable wrench is being used, be sure it is screwed tightly on the nut and that it is held in the correct position with the arm at right angles to the handle. This is the most effective angle for pulling and will prevent the wrench from slipping off the nut. Stop pulling on the nut as soon as it is turned down tight.

Do not exert a hard pull on a pipe wrench until it has a firm grip on the work; it may slip and damage the job or cause the worker to fall. Particular care should be taken when working on a ladder, scaffold, or in any elevated position.

6. Holding devices.—*a. General.*—Vises and clamps are tools used for holding work of various kinds on which some operation is being performed. The most commonly used types are shown in figures 14 and 15.

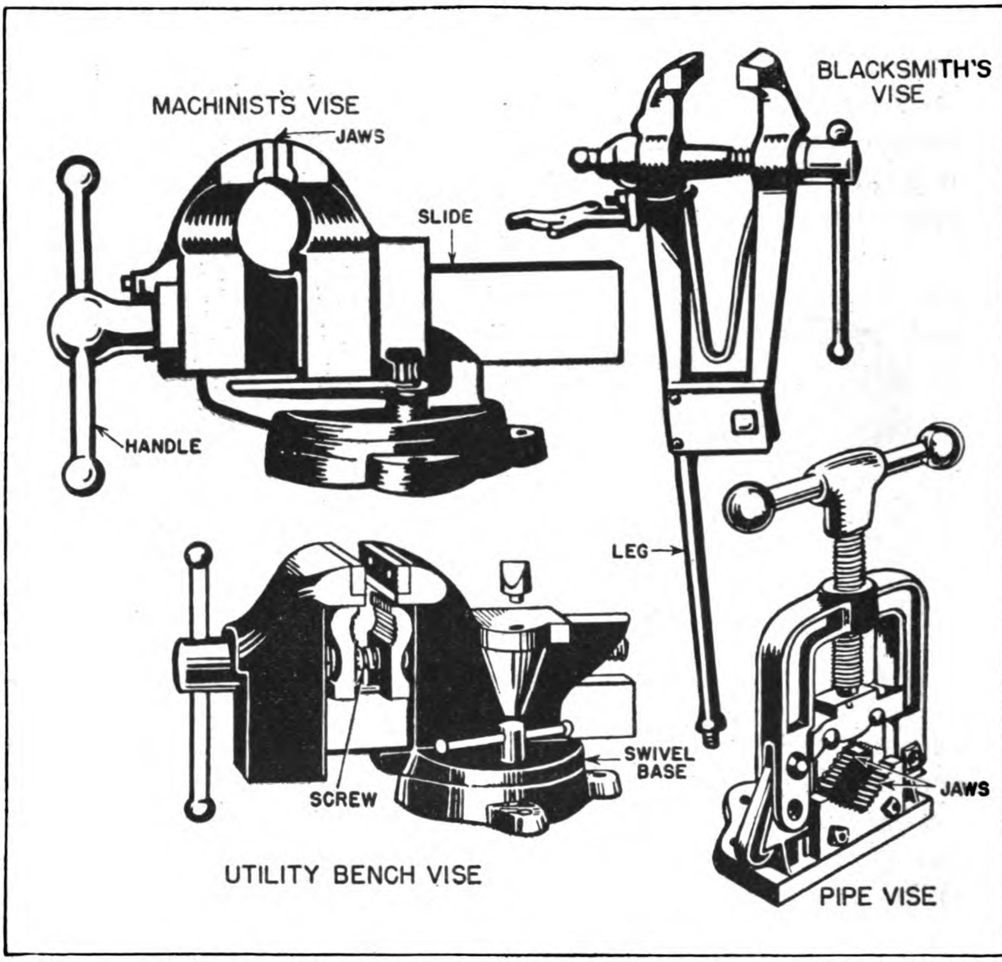

FIGURE 14.—Types of vises.

(1) *Vises.*—The vises ordinarily used in the automotive shop are the machinist's vise, the utility bench vise, the blacksmith's vise, and the pipe vise. The machinist's vise is the most commonly used in automotive work; it has flat jaws and usually a swivel base, and is suitable for most ordinary metal work. The utility bench vise has scored, removable jaws and is also equipped with pipe jaws and an anvil-faced back jaw. This vise will hold heavier work than

the machinist's vise and will also grip pipe or round rod firmly; the back jaw can be used as an anvil for light work. The blacksmith's vise can be fastened to the work bench, with its long leg fitted into a solid base on the floor; it is used for holding work that must be pounded hard with a heavy hammer. The pipe vise is used only for holding pipe or round rod.

(2) *Clamps.*—Clamps (fig. 15) are used for holding work outside of a vise and can be used where no vise is available. Generally they

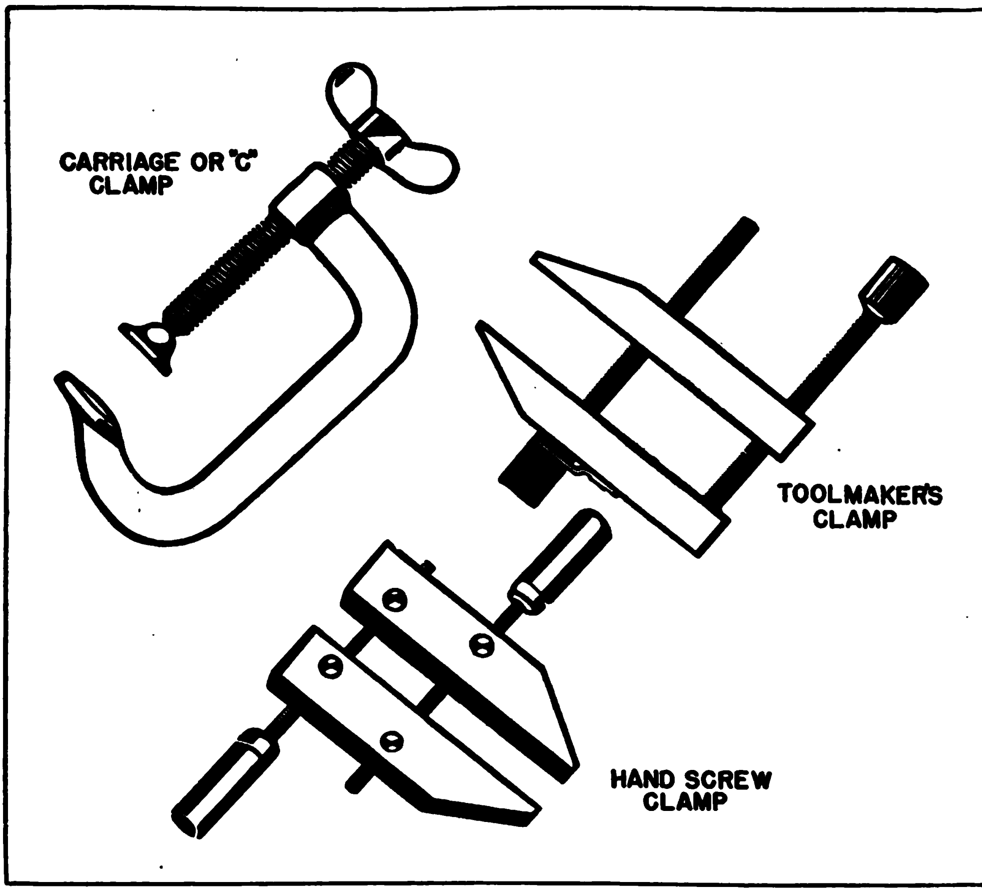

FIGURE 15.—Clamps.

are used only for light work, although heavy clamps are manufactured.

b. Use of vise.—Work clamped in the vise is roughly divided into work of light section, heavy section, irregular shapes, and round shapes.

(1) Work of light section, or of soft material, must be clamped lightly so its surface will not be damaged or its shape altered.

(2) Work of heavy section, or hard material, must be clamped

securely, so the screw of the vise is pulled up tight. The best way to do this is to turn the screw up fairly tight and then give a sharp, quick push on the end of the handle. This will give the screw a final tension. When using extra large vises, use both hands and a sharp, quick surge of the body for final tightening.

(3) Irregularly shaped work requires care and thought before clamping it in a vise. The jaws must grip on a firm, even surface. Sometimes it is difficult to find a suitable holding position. Swivel-jaw vises permit one jaw to swivel for holding tapered or irregular work; a tapered pin holds this jaw in its normal position and must be removed to allow the jaw to swivel.

(4) Round work is often clamped between straight jaws, but it is often better to fit loose jaws with V-cuts in them over the regular vise jaws. Such loose jaws are very desirable when there is enough round work on hand to justify improvising them.

(5) For clamping finished work, it is best to use loose jaws made of soft metal such as copper, brass, or lead. These jaws must be kept free of grit or they may damage the work. For holding highly polished metal, such as bearings, a piece of rawhide or soft leather laid over the vise jaws will prevent damage to the polished surface.

c. Care of vise.—For satisfactory operation keep the vise clean, oiled, and in good general condition. This applies especially to the slide and to the screw which operates the movable jaw. Lubricate the screw frequently with light grease or heavy cylinder oil; wipe the slide clean every day and spread light machine oil over it with the fingers. Never oil the swivel joint of a vise; its holding power will be impaired. The vise handle should never be hit with a hammer. When the vise is not in use, jaws should be brought lightly together with handle in vertical position.

d. Safety precautions.—Be sure to keep the fingers clear of the jaws when clamping work in the vise, and use care to keep them from being pinched between the end of the handle and the head of the screw; this accident is a very common one. When holding heavy work in a vise, it is advisable to put a block of wood or metal under the work as a prop to prevent it from sliding down and perhaps falling to the floor or on the foot. Care should be exercised in not opening the vise beyond the limit of the screw as the movable jaw may drop off and the user suffer painful or serious injury.

7. Files and filing.—*a. General.*—Files are hardened steel tools for cutting, removing, smoothing, or polishing metal. The cutting edges (or teeth) on their surfaces are made by diagonal rows of chisel cuts, as shown in figure 16. The rasp, shown in the same figure, is

similar to the file except that it has coarse teeth raised by a triangular punch. Files are classified as single cut or double cut (figs. 17 and 18). The terms "bastard," "second cut," "smooth," and "dead smooth" refer to the distance between the parallel cuts. Files are made in various shapes, as shown in cross section in figure 19, and are from 3 to 24 inches long.

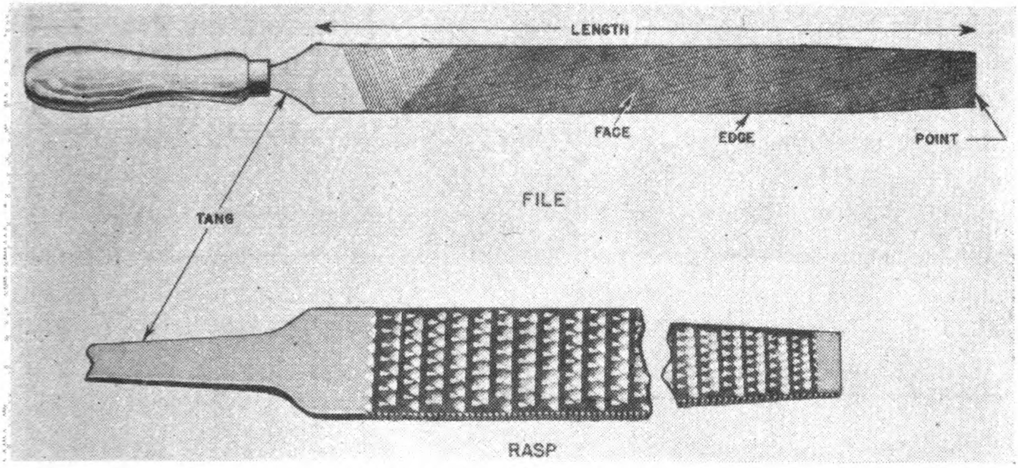

FIGURE 16.—File and rasp.

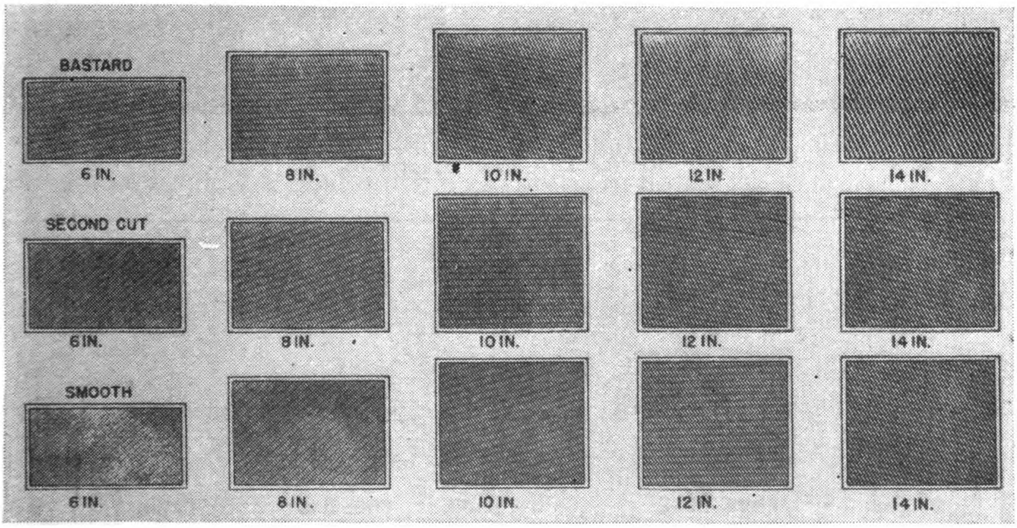

FIGURE 17.—Single cut files.

b. Commonly used files are—

(1) *Mill file.*—A single cut file tapering in thickness and width for one-third of its length. It is useful for fine work. This file is available with either square or round edges or with one safe edge. (The safe edge is smooth and has no cutting teeth.)

(2) *Flat file.*—A double cut file tapering in thickness and width, used principally when a fast cutting tool is desired. The mill file (single cut) is commonly accepted as a type of flat file, although all files designated as flat files are double cut.

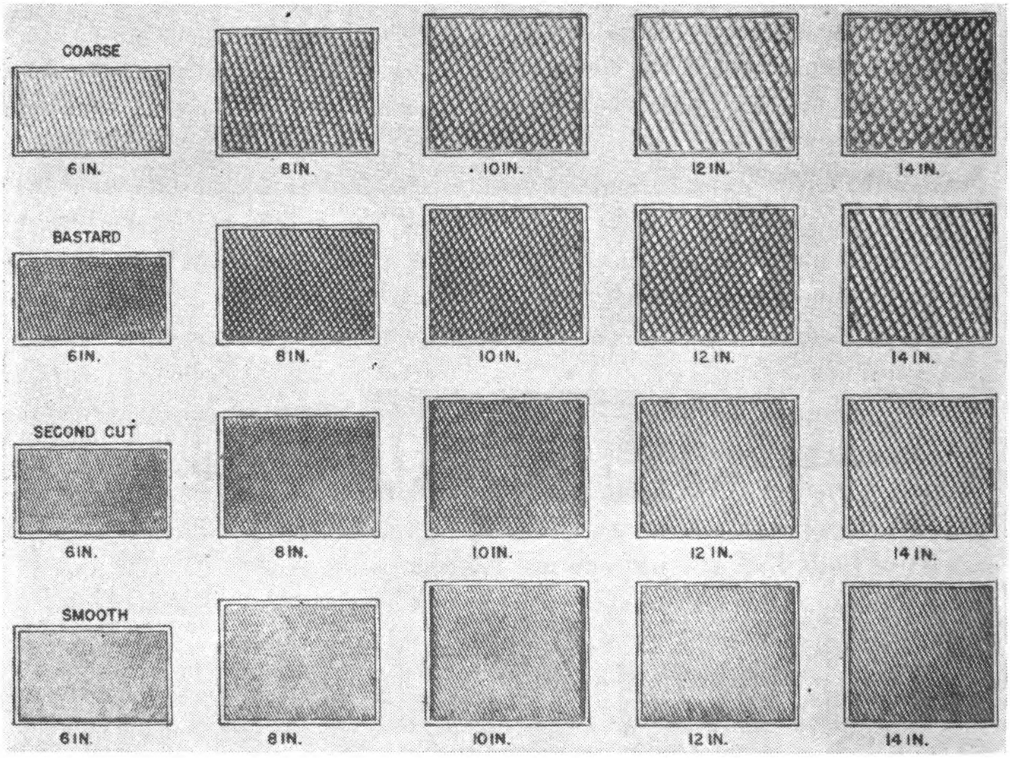

FIGURE 18.—Double cut files.

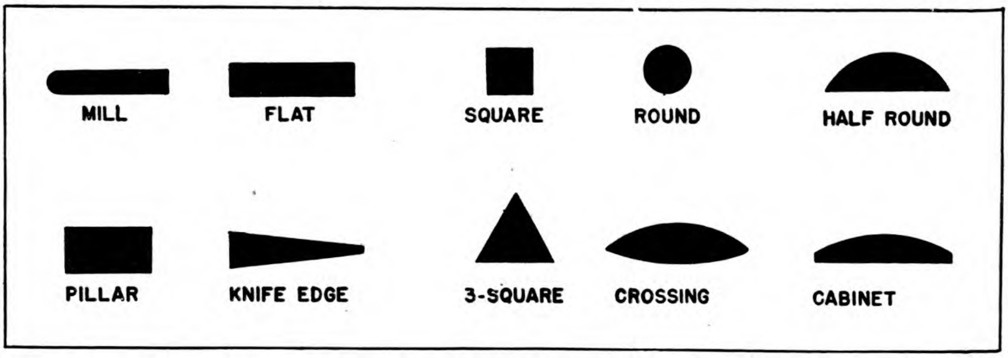

FIGURE 19.—Shapes of files.

(3) *Round file.*—A round tapered file usually single cut but sometimes double cut in the larger sizes; it is sometimes called "rat-tail" file. Parallel or untapered, round files are also available. The principal use of these files is to enlarge circular openings or concave surfaces.

(4) *Hand file.*—A single cut file, similar in shape to a flat file, with parallel sides and a slight taper in thickness. It has square edges, one of which is a safe edge.

(5) *Warding file.*—A double cut file, similar in shape to a mill file, with tapering sides and about two-thirds the thickness of a mill file. Warding files are used for filing narrow slots or grooves.

(6) *Half-round file.*—A double cut file tapering in thickness and width, with one flat and one oval side. This file is used for removing stock rapidly and for filing concave surfaces.

(7) *Special files.*—Other files in almost any shape and size are available for special purposes. A small flat file of special composition, known as an ignition file, is used extensively in automotive work for filing tungsten breaker contact points.

c. Selecting correct file.—(1) For heavy, rough cutting, a large coarse, double cut file is best.

(2) For finishing cuts, use a second cut or a smooth single cut file.

(3) When filing cast iron, start with a bastard cut file and finish with a second cut.

(4) When filing soft steel, start with a second cut file and finish with a smooth cut.

(5) When filing hard steel, start with a smooth cut file and finish with a dead smooth.

(6) When filing brass or bronze, start with a bastard cut file and finish with a second or smooth cut.

(7) When filing aluminum, lead, or babbitt metal, use a bastard file or, better still, a float cut file as shown in figure 20.

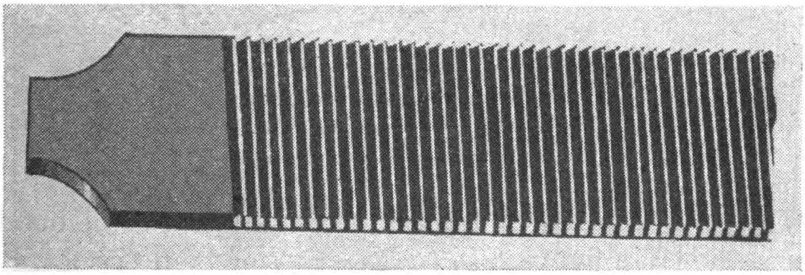

FIGURE 20.—Float cut file.

(8) For small work, use a short file; for medium-sized work, use an 8- or 10-inch file; for large work, use a file as large as can be controlled conveniently.

d. Using a file.—(1) The correct way to hold a file is with the handle against the palm of the right hand, thumb on top, as shown in figure 21. Hold the end of the file in the left hand with the fingers

curled under it, as shown. When filing, lean the body forward during part of the forward stroke and straighten up at the finish. The file must be held straight or the surface of the work will not be flat. Not more than 30 or 40 strokes per minute should be taken; too much speed will ruin the file and the work.

(2) Apply pressure on the *forward stroke only.* Unless the file is lifted from the work on the return stroke, it will become dull much sooner than it should. (This does not apply when filing very soft metals, such as lead or aluminum. On soft work, pressure on the return stroke helps keep the cuts in the file clean of removed metal.) Apply only enough pressure to make the file cut evenly.

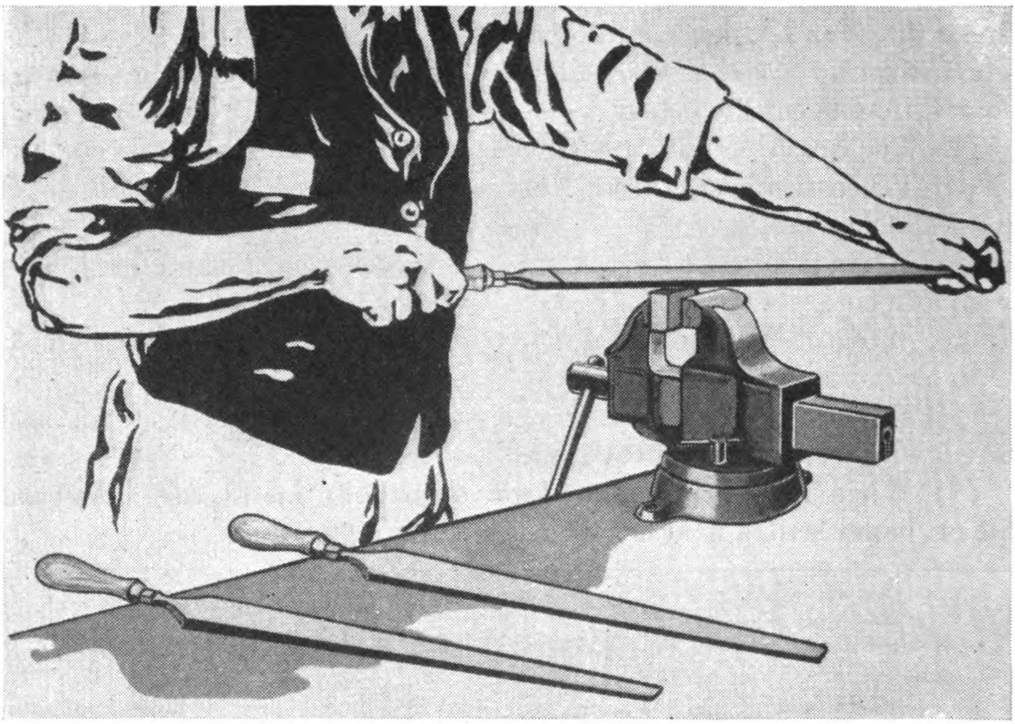

FIGURE 21.—Correct way to hold file.

(3) When round surfaces are filed, best results will be obtained by working as shown in figure 22, a rocking motion being used.

(4) It is bad practice to bear down hard on a new file. When the file is new, the teeth are very fine and will not stand much pressure.

(5) Hold the work firmly in a vise, with the surface to be filed projecting slightly above the vise jaws, and parallel with them, as shown in figure 21. To avoid damage to the work, detachable jaws or pieces of soft metal, such as copper or lead, can be placed between the work and the vise jaws. If the work is loose in the vise, the file will chatter, which damages its teeth.

(6) To produce a very smooth surface, work is sometimes "draw-filed." In draw filing, move the file sidewise along the work, as shown in figure 23. A single cut smooth file should be used. Pressure is heaviest on the stroke made toward the body and very light on the return.

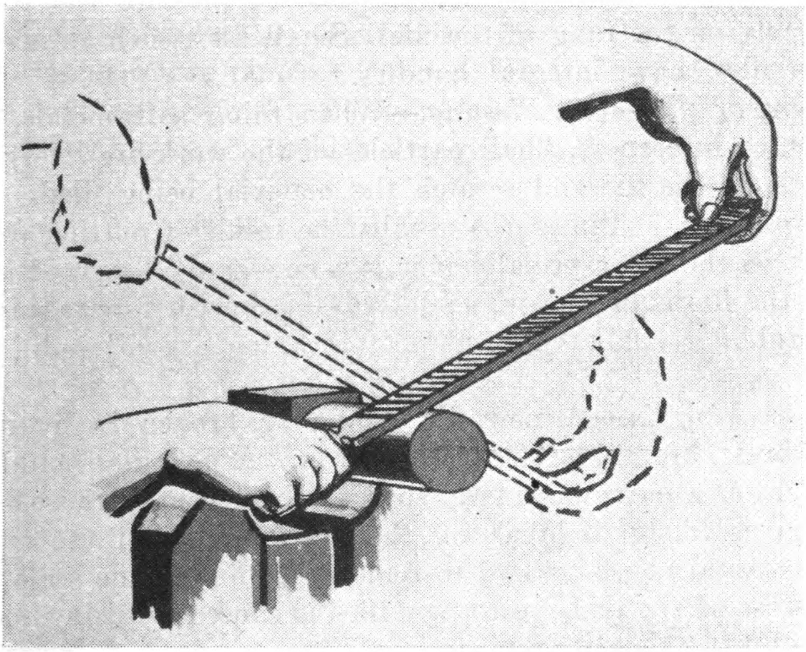

FIGURE 22.—Filing round surfaces.

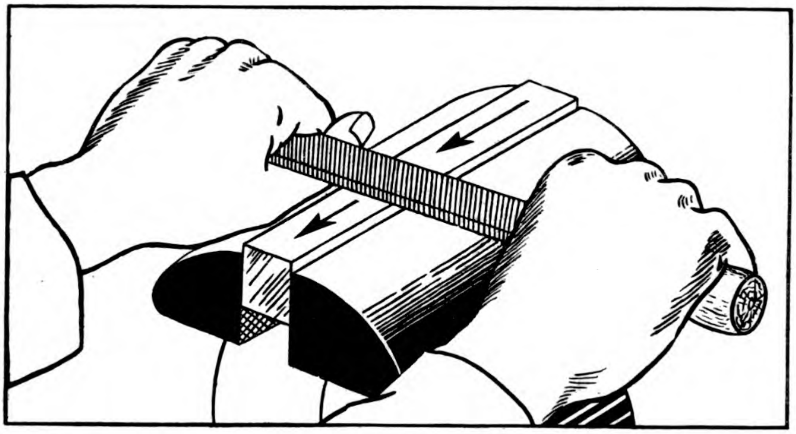

FIGURE 23.—Draw filing.

(7) For a still smoother surface than can be obtained by draw filing, wrap a piece of fine emery cloth around the file and proceed as in draw filing.

(8) When filing work which is rotating in a lathe, long, slow cuts give best results. The work must be rotating at high speed.

For rough work, a double cut flat file is generally used. For finishing work, a mill file gives better results, as it is a single cut file and has a shearing action. Too much filing of a piece of work in a lathe will as a rule, spoil it by throwing it out of round.

(9) No file with a tang should *ever* be used without a handle, as the tang may run into or cut the hand. Be sure the handle is held firmly on the tang of the file. Small files, such as needle and ignition files, have integral handles.

e. Care of file.—(1) *Pinning.*—When filing soft metals, narrow surfaces, or in corners, small particles of the work are likely to clog the teeth of the file and scratch the material being filed. This is called "pinning." Pinning is usually the result of putting too much pressure on the file, especially if it is a new one. To avoid pinning, be sure the file is broken in, as described below, before taking heavy cuts. Rubbing chalk on a file before using it will help prevent pinning.

(2) *Breaking in.*—A new file should be broken in by using it first on brass, bronze, or smooth cast iron. A new file should not be broken in on a narrow surface, such as sheet iron, because the narrow edge is likely to break off the sharp points of the teeth. A new file should never be used to remove the fins or the scale on cast iron. Most of the damage to new files is caused by using too much pressure during the first few strokes.

(3) *Cleaning.*—If a file is pinning or not cutting properly, it should be cleaned with a file card, pick, and brush. (See fig. 24.) The pick is a small, pointed wire instrument, often furnished with a file card, for cleaning out individual cuts in the file clogged too tightly with metal to clean with a file card. When cleaning a file, lay it flat on the bench and draw the file card and brush back and forth across it parallel with the cuts. Finish by brushing the file lengthwise.

(4) *Materials.*—A file should never be used on material harder than itself or on a sandy or scaly casting. One stroke across such sand or scale will make the file useless. To prevent scratching or cutting too deep when filing wrought iron, steel, or hard fiber, apply a little oil to the surface of the file.

(5) *Handling.*—Like any cutting tool, a file is easily dulled by rough or improper handling. Files should not be thrown into a drawer or box where they can rub against each other or against other tools. It is best to store them in separate holders, such as clips, straps, or holes cut in a wooden block. Too rapid strokes or failure to lift the file off the work on the return stroke will quickly

spoil its cutting efficiency. For best results and long file life, use the file card and brush often.

f. Safety precautions.—The following suggestions will help one to use files without personal injury:

(1) Never use a file without a firmly attached handle, particularly when filing work rotating in a lathe.

(2) Do not salvage a small rat-tailed file for the purpose of using it as a prick or center punch.

(3) Never use a file for a pry. It is almost sure to break and throw off tiny bits of steel which may get into the eye.

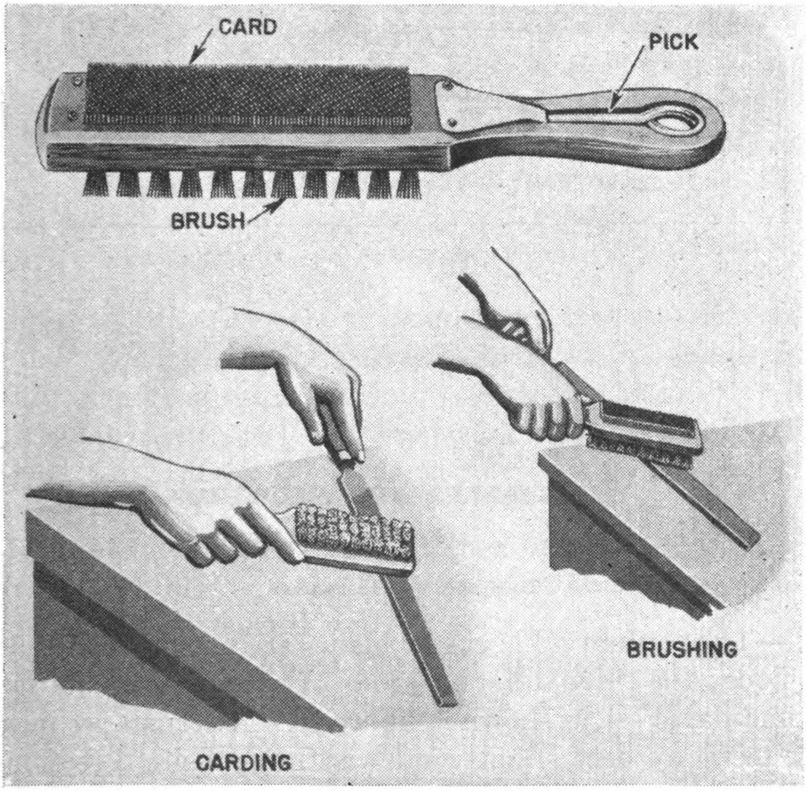

FIGURE 24.—Cleaning a file.

(4) Never use a file as a hammer; this will not only injure the file, but it may throw steel particles into the eyes.

8. Hacksaws.—*a. General.*—Hacksaws are saws used for cutting metal, much as a carpenter's saw cuts wood. Common hand hacksaws have either adjustable frames or solid frames, as shown in figure 25. Hacksaw blades of various types are inserted in these frames for different kinds of work. Adjustable frames can be changed to hold blades from 8 to 16 inches long; solid frames, although more rigid, will take only the length blade for which they are made. This length

is the distance between the two pins which hold the blade in place. All hacksaw frames hold the blades either parallel or at right angles to them and are provided with screws for pulling the blades tight.

b. Hacksaw blades.—Hacksaw blades are made of high grade tool steel, hardened and tempered. There are two types: the all-hard and the flexible. All-hard blades are hardened throughout, while only the teeth of flexible blades are hardened. All blades are from $\frac{7}{16}$ to $\frac{9}{16}$ inch wide, have from 14 to 32 teeth per inch, and are from 8 to 16 inches long. Each blade has a hole at each end which hooks to pins in the frame.

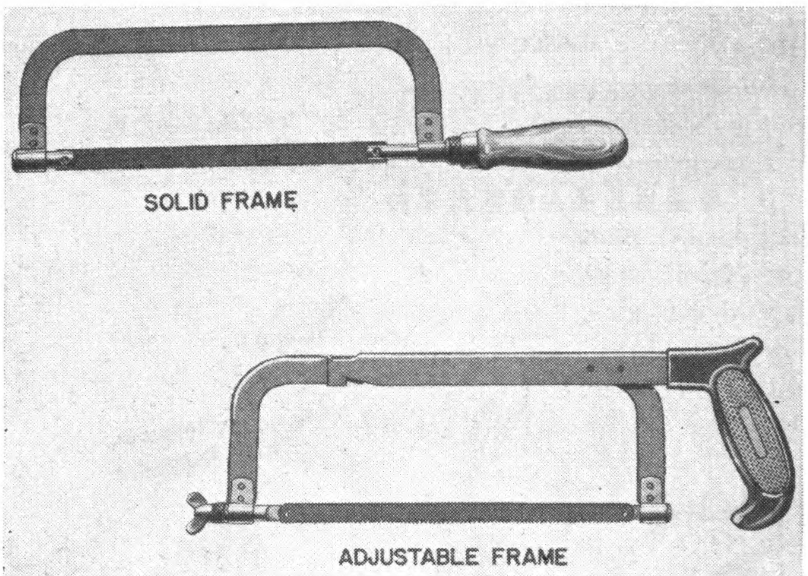

FIGURE 25.—Hacksaws.

c. Set.—The teeth of all hacksaw blades are set to provide clearance for the blade; the three different kinds of set are alternate set, raker set, and undulated set, as shown in figure 26. Alternate set means that alternate teeth are bent slightly sidewise in opposite directions; on a raker set blade, every third tooth remains straight, and the other two are set alternately; on an undulated set blade, short sections of teeth are bent in opposite directions. A blade should be set just enough to give a free, smooth, rapid cut in a slot just wider than the blade itself, removing no more stock than is necessary.

d. Selecting hacksaw blades.—(1) Selecting the best hacksaw blade for a specific job is a question of using either an all-hard or flexible blade having a pitch (number of teeth per inch) best suited to the work in hand. The usual practice is as follows:

(*a*) An all-hard blade is best for sawing brass, tool steel, cast iron, rails, and other stock of heavy cross section.

(*b*) In general, a flexible blade is best for sawing hollow shapes and metals of light cross section, such as channel iron, tubing, tin, copper, aluminum, or babbitt.

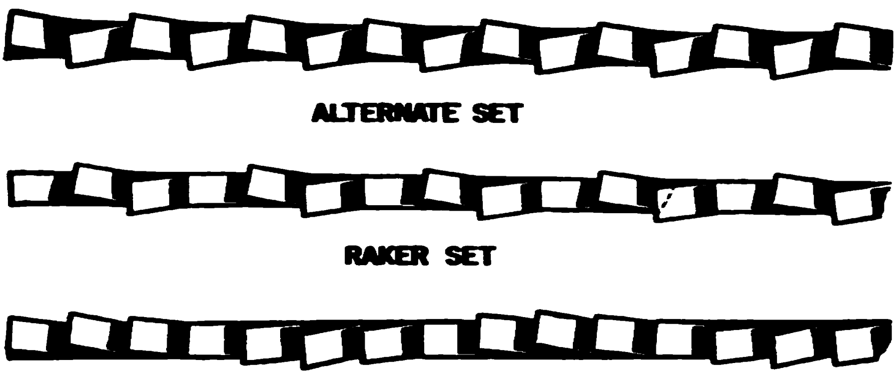

FIGURE 26.—Set of hacksaw blade teeth.

(2) Figure 27 illustrates the principles involved in selecting blades with the most suitable pitch for most jobs. The following procedure will usually give good results:

(*a*) Use a blade with 14 teeth per inch on machine steel, cold rolled steel, or structural steel. This coarse pitch makes the saw free and fast cutting.

(*b*) Use a blade with 18 teeth per inch on solid stock, aluminum, babbitt, tool steel, high speed steel, cast iron, and so on. This pitch is recommended for general use.

(*c*) Use a blade with 24 teeth per inch on tubing, tin, brass, copper, channel iron, and sheet metal over 18 gage. If a coarser pitch is used, the thin stock will tend to strip the teeth out of the blade and make it difficult to push the saw. Two or more teeth should be in contact with the work, as figure 27 clearly shows.

(*d*) Use a blade with 32 teeth per inch on thin-walled tubing and conduit and on sheet metal thinner than 18 gage.

e. Using a hacksaw.—After selecting the correct blade and seeing that it is stretched tight in the frame—

(1) Mark the stock at the point to be cut with a scriber, soapstone, or pencil. If special accuracy is required, nick the work with a file and start the saw in the nick.

(2) Be sure the work is gripped tightly in a vise, with the line to be cut as close to the vise jaws as possible. In cutting angle iron or

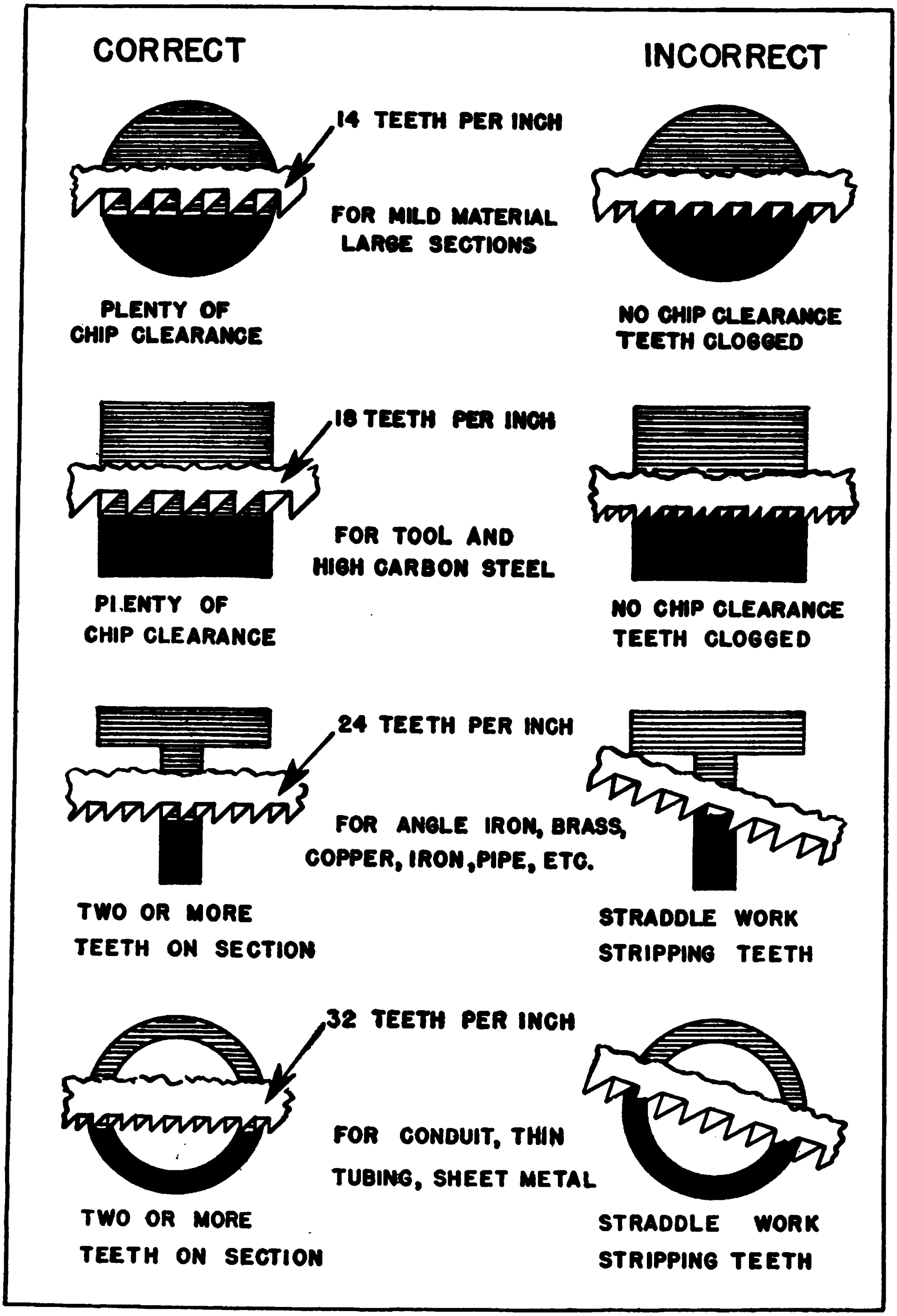

FIGURE 27.—Correct pitch of hacksaw blades.

any odd-shaped work, expose as much surface as possible so that a corner may be taken gradually and the maximum number of teeth engaged throughout the cut. It is best to start cutting on the widest surface of the work. Figure 28 shows the right and wrong ways to start hacksaw cuts. The hacksaw should be held vertically and moved

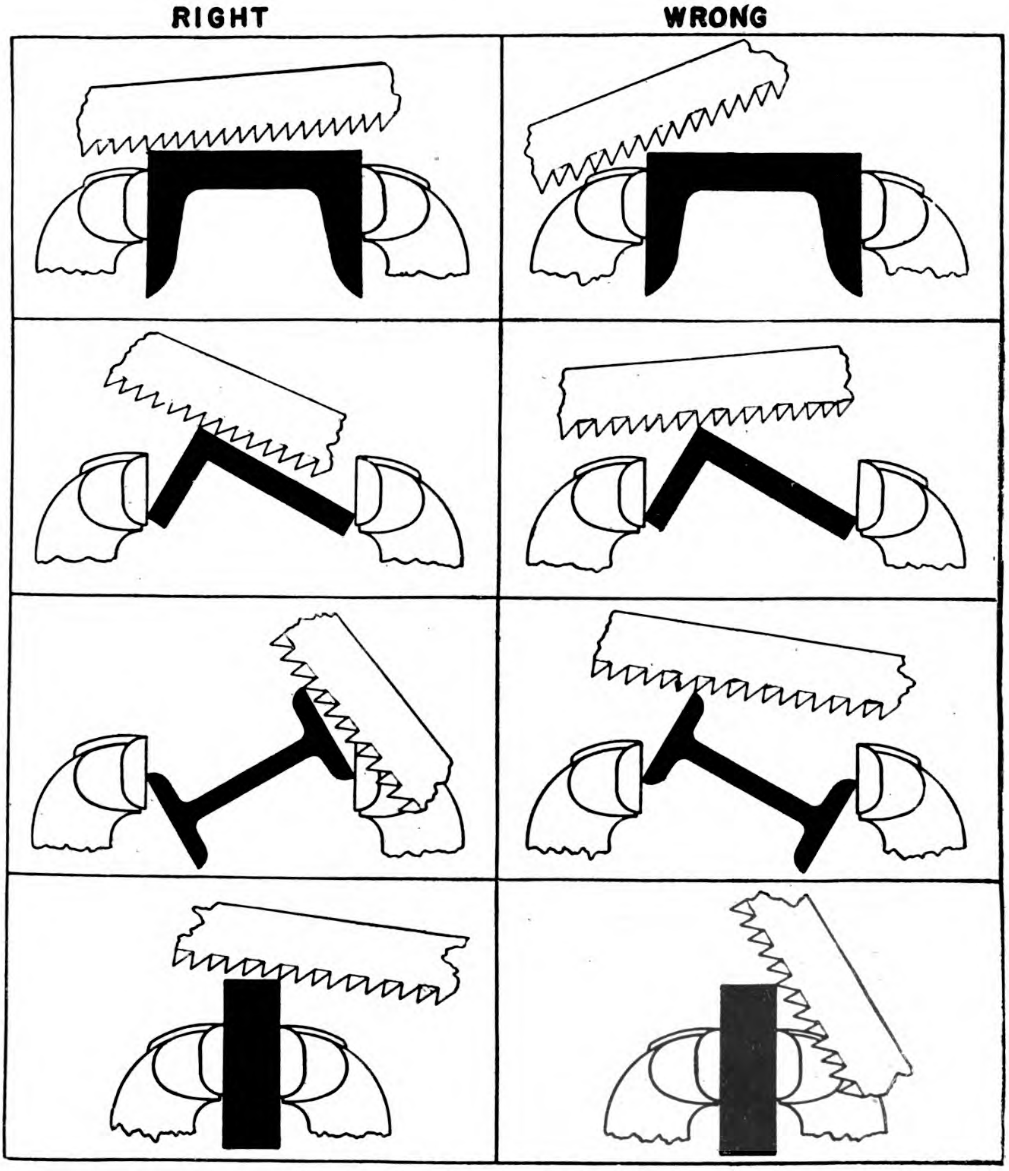

FIGURE 28.—Starting hacksaw cuts.

forward with a light, steady stroke. At the end of the stroke, relieve the pressure and draw the blade *straight back*. After the first few strokes, make each one as long as possible without striking the saw frame against the work. Do not bear down on the saw on the return

stroke. Keep the saw in the same plane throughout the cut, otherwise the blade may be cramped and broken. To make a cut deeper than the frame, turn the blade sidewise, as shown in figure 29. The most effective cutting speed is from 50 to 60 strokes per minute. When the work is nearly cut through, raise the saw slightly to prevent the teeth from catching. Special care is needed toward the end of a cut through thin material. When cutting very thin stock, it is advisable to clamp the work between two pieces of wood or soft metal and saw through all three pieces; this will prevent chattering and possible damage to the work.

f. Safety precautions.—The chief danger in using hacksaws is injury to the hand when a blade breaks. The blade will break if one bears down too hard on the cut or does not push the saw in a straight line. If the work is not tight in the vise it will sometimes slip, twisting the blade enough to break it.

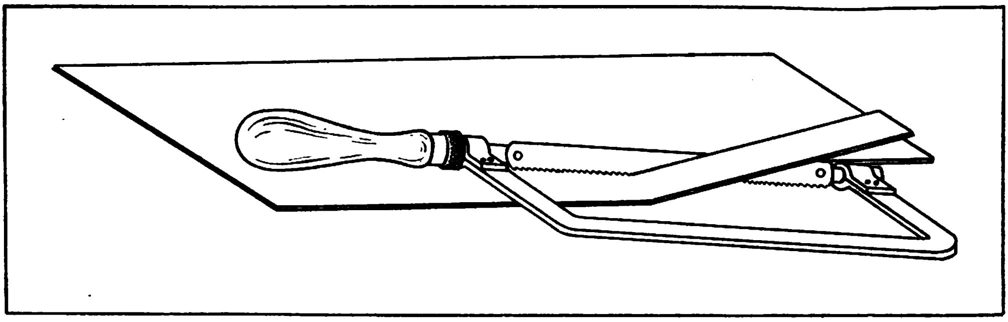

FIGURE 29.—Making cut deeper than frame.

9. Punches and punching.—*a. General.*—Punches (fig. 30) are used to locate centers for drawing circles, to start holes for drilling, or to punch holes in metal sheets which are 24-gage or thinner. The two kinds of punches generally used are solid and hollow. Solid punches are classified according to the shape of their points: pin punches, taper punches, solid punches, prick punches, and center punches.

(1) Center punches are intended for starting holes to be drilled with a twist drill.

(2) Prick punches are generally used for marking centers or other locations on metal.

(3) Pin punches are used for driving out straight or tapered pins.

(4) Holes from $\frac{1}{16}$ up to $\frac{1}{4}$ inch in diameter usually are made with a solid tapered punch with a flat end.

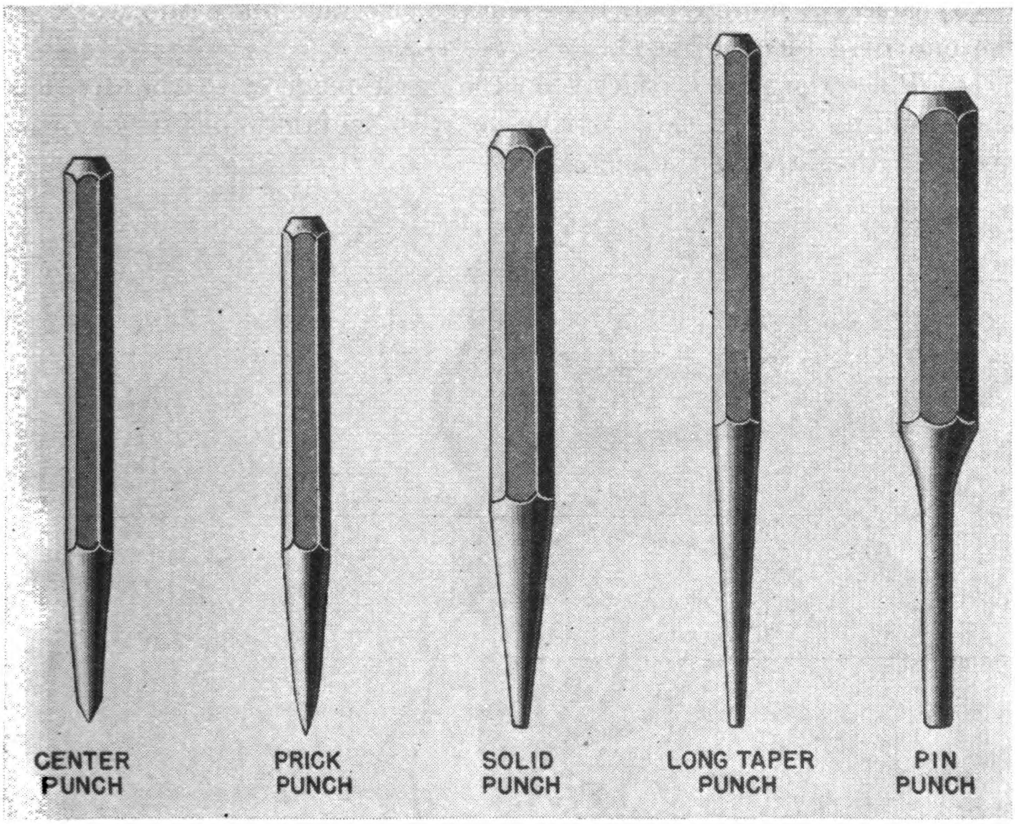

FIGURE 30.—Types of solid punches.

b. Use of solid punches.—To punch holes in metal with a solid punch, the following procedure, illustrated in figure 31, is recommended:

(1) Locate the position at which the hole is to be and mark the work lightly with a center punch.

(2) Select a sharp solid punch of the desired size and place the work on the end of a block of wood.

(3) Hold the punch in a vertical position, being sure it is exactly on the mark made with the center punch. Then strike it with a fairly heavy hammer until it cuts through the metal.

c. Use of hollow punches.—In using a hollow punch to make holes in sheet metal, the following procedure, illustrated in figure 32, will give good results:

(1) Locate the center of the hole to be punched and mark the work lightly with a prick punch.

(2) Set a pair of dividers to half the diameter of the hole desired and using the prick punch mark as the center make a distinct circle on the work. This circle will have the same diameter as the hole to be punched.

(3) Select a hollow punch of correct size and place the work on the end of a block of wood.

(4) Place the punch exactly on the circle made with the dividers and, holding it vertically, strike it with a fairly heavy hammer until it cuts through the metal.

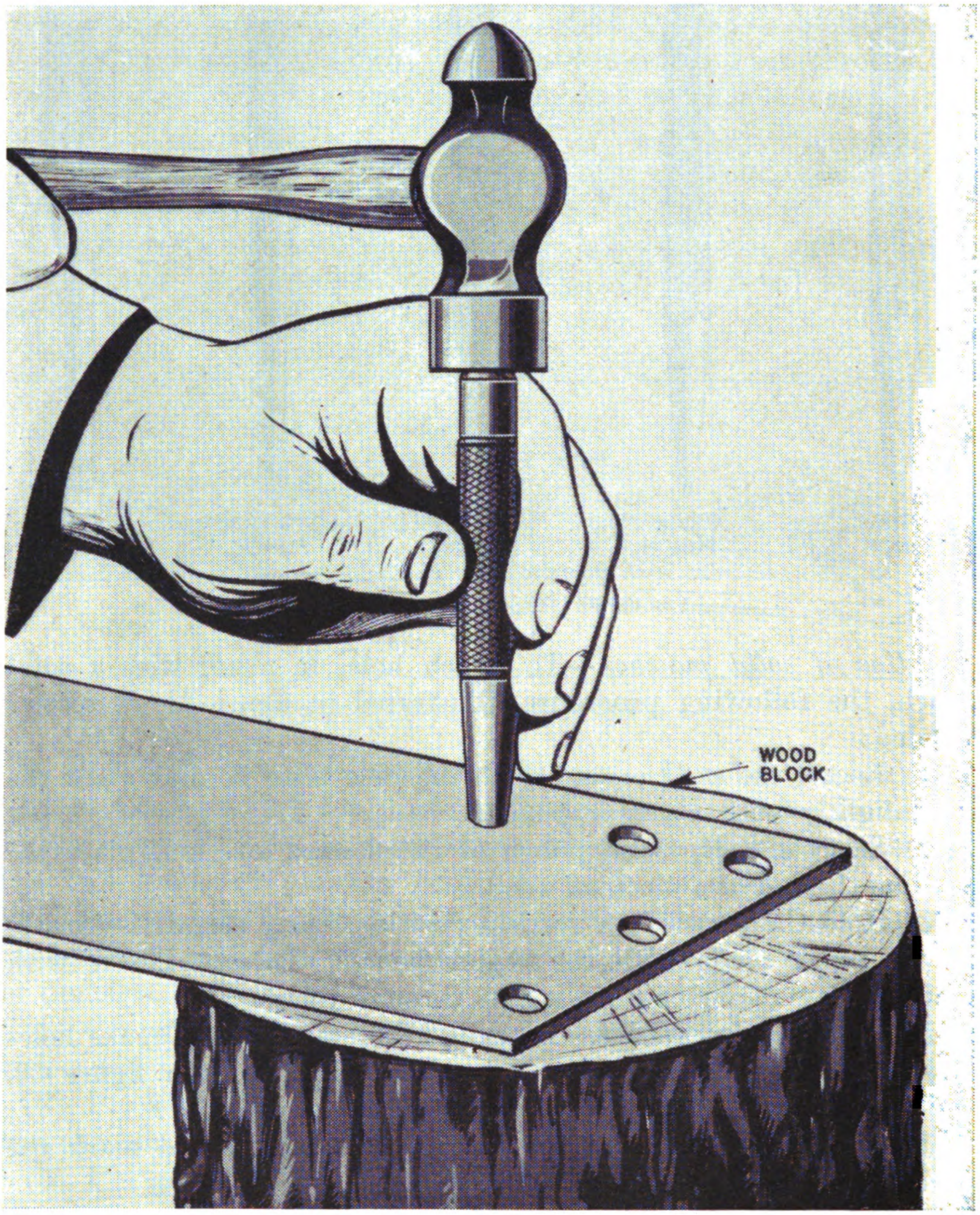

FIGURE 31.—Using a solid punch.

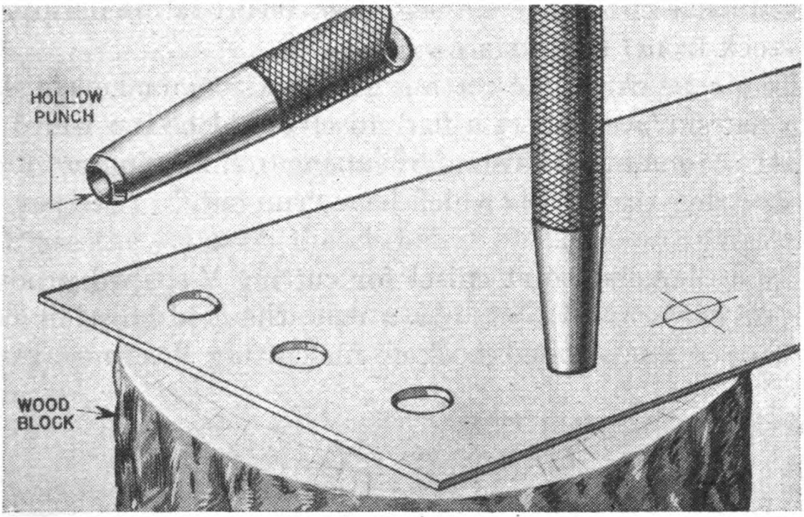

FIGURE 32.—Using a hollow punch.

10. Chisels and chipping.—*a. General.*—Cold chisels are tools used for chipping or cutting cold metal by hand before its surface has been filed to a fit, an operation often required in automotive maintenance work. They are made of a good grade of tool steel, hardened at the point, sharpened to a cutting edge at one end and, in hand work, driven by a hammer. They will cut any metal softer than they are; in general, any material that can be cut with a file. They are classified (fig. 33) according to the shape of their points, the commonest shapes being flat, cape, roundnose, and diamond-point.

b. Selecting a cold chisel.—Best results will be obtained if a type of cold chisel is selected that is designed for the particular work to be done.

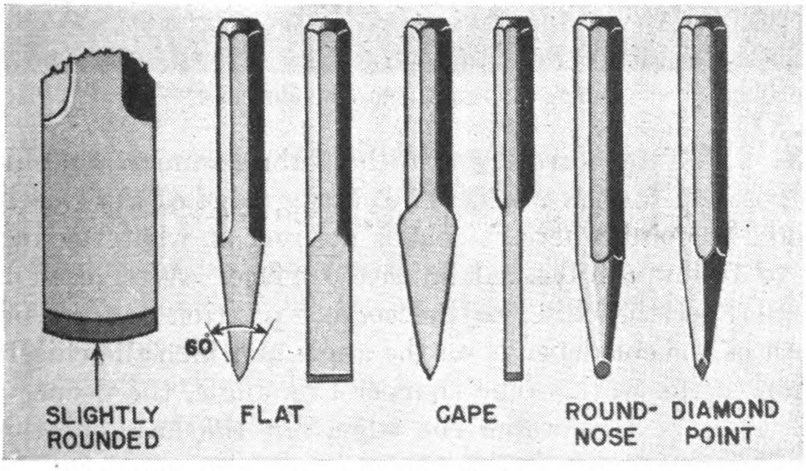

FIGURE 33.—Commonly used cold chisels correctly sharpened.

(1) Use a flat chisel for cutting sheet metal or for chipping (removing stock from) flat surfaces.

(2) Use a cape chisel for cutting grooves, slots, or keyways, or for chipping flat surfaces where a flat chisel would be too wide.

(3) Use a roundnose chisel for cutting round (concave) grooves and for drawing back drills which have "run out." (See par. 11*b*(1) (*b*).)

(4) Use a diamond-point chisel for cutting V-shaped grooves.

c. Use of cold chisels.—(1) As a rule, the cold chisel is used for cutting wire or small round stock or for cutting sheet metal or plate.

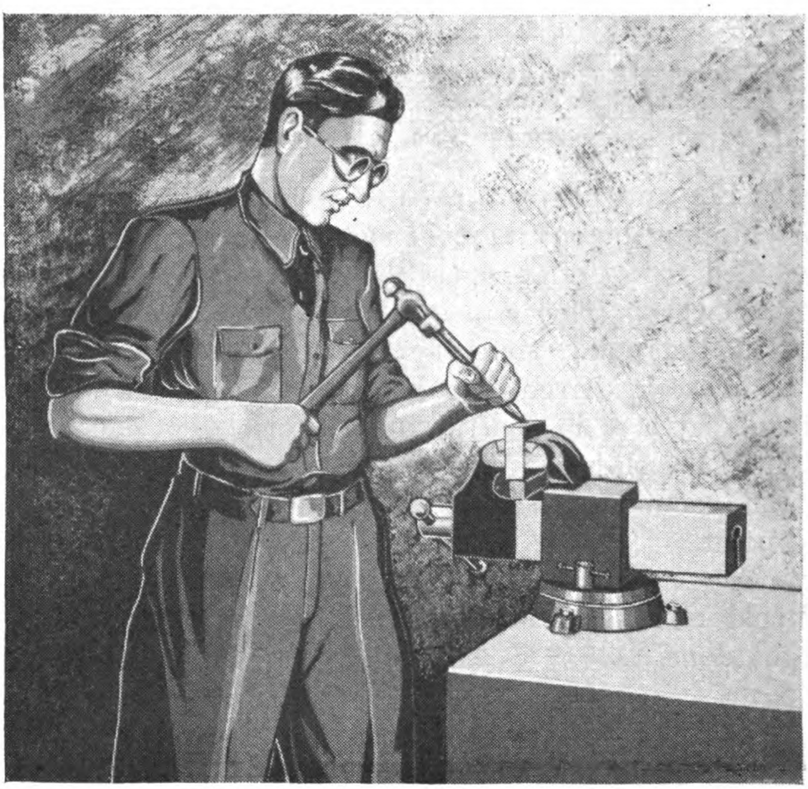

FIGURE 34.—Correct use of cold chisel.

Figure 34 shows the correct way to hold the hammer and chisel and the best position for the work. The cutting edge of the chisel should be held at the point where the cut is desired, at whatever angle will cause it to follow the desired finished surface. After each blow of the hammer, set the chisel to the correct position for the next cut. The depth of the cut depends on the angle at which the chisel is held in relation to the work. The sharper this angle, the deeper the cut will be. It is best to watch the edge, not the head, of the chisel while working. Sharp, quick blows should be struck, taking care

that the hammer does not slip off the end of the chisel and injure the hand.

(2) When cutting wire or round stock, the following procedure will be found satisfactory:

(*a*) Mark with chalk or colored pencil the point at which the cut is to be made.

(*b*) Place the work on the chipping block of an anvil or on any soft metal support.

(*c*) Hold the chisel as shown in figure 35, with the cutting edge on the chalk or pencil mark and the body of the chisel in a vertical position.

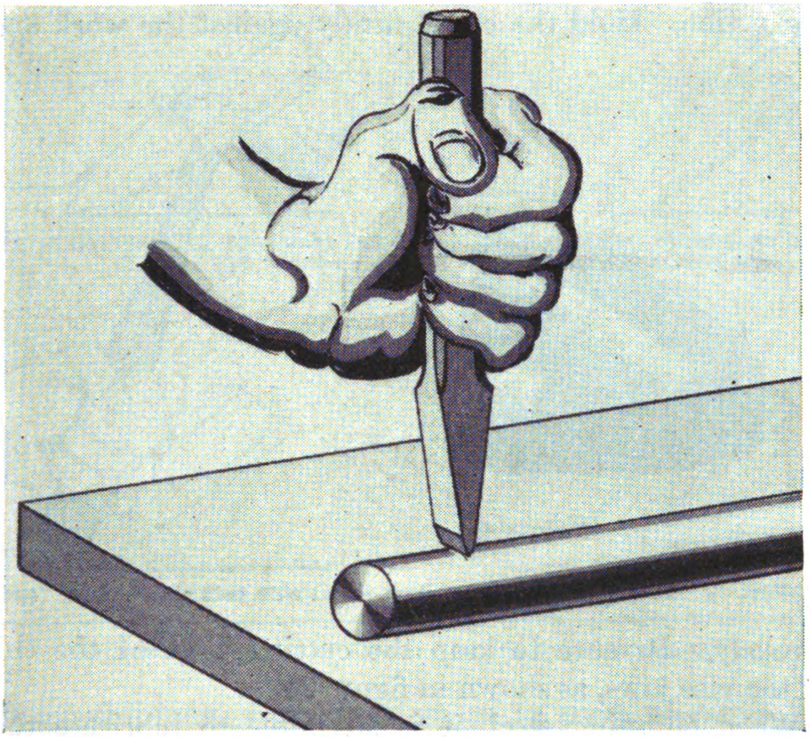

FIGURE 35.—Cutting round stock with cold chisel.

(*d*) Strike the chisel a light blow with the hammer, and examine the chisel mark on the work to make certain the cut is at the desired point.

(*e*) Drive the chisel into the work with vigorous blows. The last stroke or two should be made lightly to avoid unnecessary damage to the supporting surface.

(*f*) Heavier work can be cut in much the same way, except that the cut is made about halfway through the stock from one side, the work turned over, and the cut finished from the opposite side.

(3) Cutting sheet or plate metal with a cold chisel should be avoided whenever possible as stretching of the metal invariably results. However, when no alternative is presented, the best procedure is as follows:

(*a*) Draw a straight line on the work with a scriber where the cut is to be made.

(*b*) Grip the work firmly in a vise with the scribed line even with or just below the top of the vise jaws, as shown in figure 36. The waste metal should extend above the jaws, as shown in the illustration.

(*c*) Using a sharp chisel, start at the edge of the work and cut along the scribed line, using the vise jaws as a base for securing a shearing action. Hold the chisel firmly against the work and strike

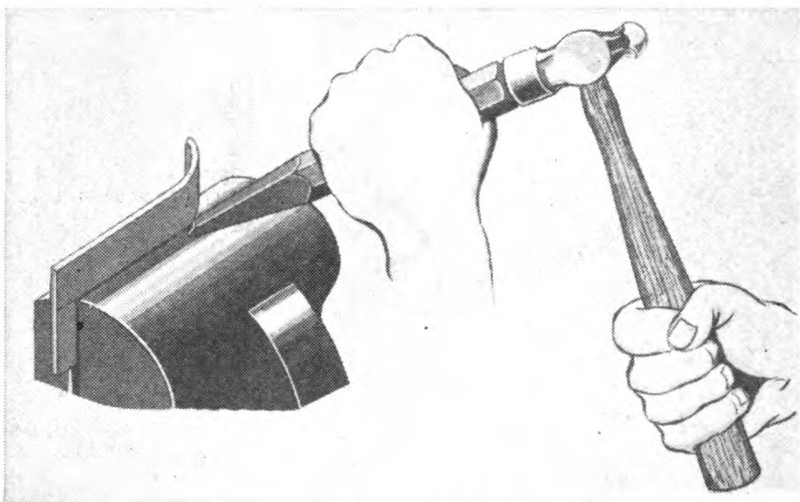

FIGURE 36.—Cutting sheet metal with cold chisel.

it vigorously. Be sure to keep the cutting edge of the chisel flat against the vise jaws, as shown in figure 36.

(4) When chipping steel, it is advisable to lubricate the chisel point with a light machine oil. This will make the chisel easier to drive and cause it to cut faster than it would if dry. When chipping cast iron, chip from the edges of the work toward its center to avoid breaking off corners.

d. Care of cold chisels.—(1) *Sharpening.*—Chisels, like all cutting tools, must be sharp to give satisfactory service. The cutting angle should be about 60° and the edge slightly rounded, as shown in figure 33. Sharpening is usually done on an ordinary coarse grinding wheel. The chisel should not be pressed too hard against the wheel, or enough heat will be generated to draw the temper out of the steel. If the cutting angle is ground too small, the chisel will not be safe

to use; or if this angle is much over 60° the tool will not cut properly. Figure 37 shows the results of correct and incorrect sharpening.

(2) *Mushroom head.*—The blows of the hammer will eventually cause the blunt end of the chisel to spread out until it resembles a mushroom. When this happens, the end should be ground back to its original shape. It is dangerous to use a chisel with a mushroom head because pieces may fly off and cause injury.

e. Safety precautions.—The following precautions should be observed when using cold chisels, both for the worker's safety and to prevent damaging either the tool or the work:

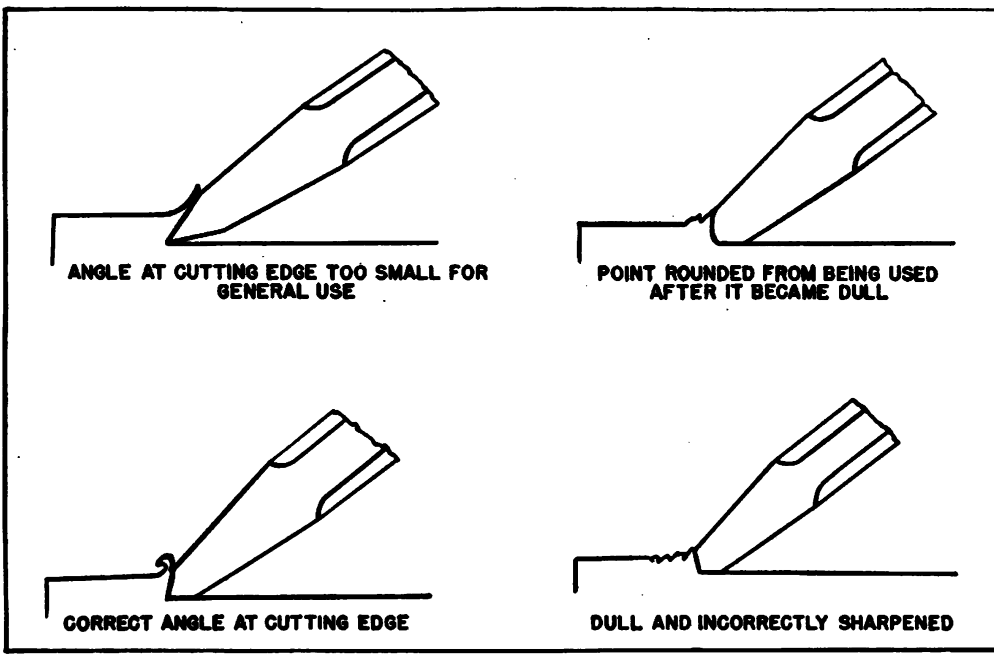

FIGURE 37.—Results of correct and incorrect sharpening.

(1) When chipping, a chipping guard (a piece of canvas about 2 feet square attached to two wooden pedestals) should be placed in front of the work to guard against flying metal chips.

(2) Always wear goggles.

(3) Keep the hammer and the blunt end of the chisel clean and free of grease or oil to prevent the hammer from slipping and bruising the hand.

(4) If the work is held in a vise, the jaws should have guards made of soft material such as copper or brass to protect the finish on the work. It is advisable to put a block under the work so it cannot slip out of the vise. Always chip toward the solid jaw of the vise; never chip toward the movable jaw. Where possible, avoid chipping parallel with the jaws.

11. Drills and drilling.—*a. General.*—The motor vehicle mechanic must often drill holes in work which cannot be placed on the table of a drill press, or when no such press is available, so it becomes necessary to use a portable electric drill or to drill by hand. The common hand tools for holding and turning drills are the hand drill, breast drill, and brace, shown in figure 38. Holes up to ¼ inch in diameter can be drilled in metal by hand effectively. The actual cutting of the holė is done by a twist drill, which when properly ground

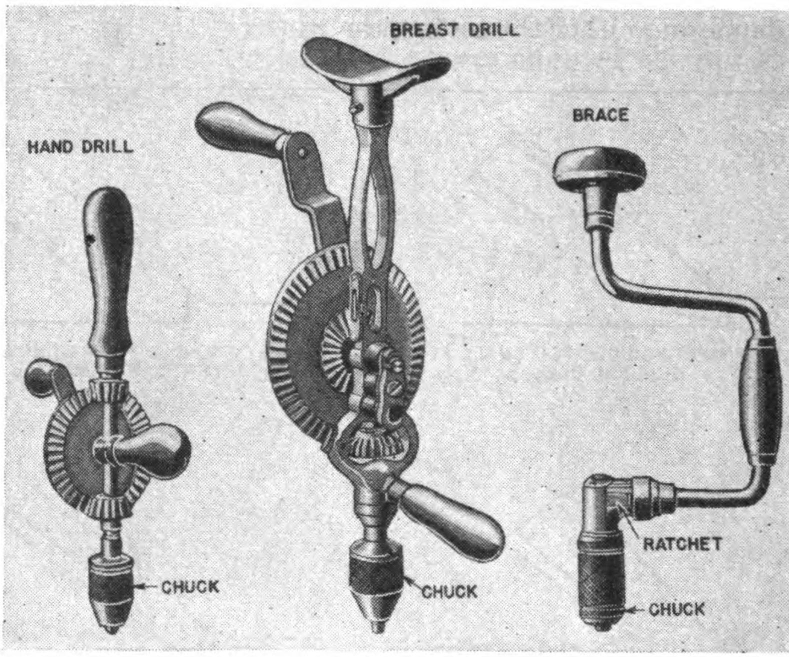

FIGURE 38.—Hand drilling tools.

(or sharpened) is a very efficient tool. Figure 39 shows a twist drill and the nomenclature of its parts. Twist drills are made either of carbon steel or high speed steel; the nature of carbon steel is such that if heated excessively and allowed to cool, it will lose its hardness; high speed steel, on the other hand, has the property of "red hardness"; that is, it can become red hot without losing its temper. For any drilling at high speed, therefore, high speed steel twist drills should be selected to obtain best results and lasting cutting effectiveness. The three principal parts of twist drill are the body, shank, and point, and they are available with either two, three, or four flutes (the spiral grooves formed along the sides), but drills having three or four flutes are used for following smaller drills or for enlarging cored holes and are not suitable for drilling into solid stock. These spiral flutes give twist drills four definite advantages:

(1) They give a correct rake to the lips, as shown in figure 40.

(2) They cause chips formed while drilling to curl tightly so that they occupy the minimum amount of space.

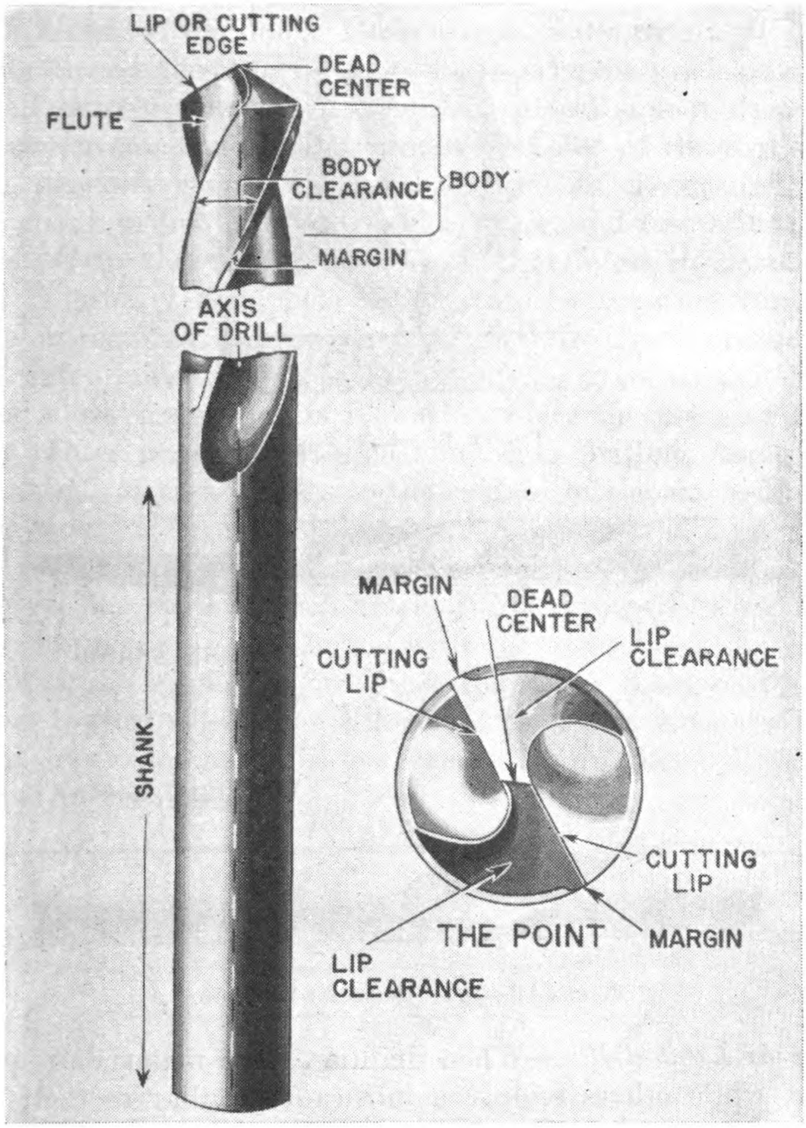

FIGURE 39.—Twist drill.

(3) They form channels through which such chips can escape from the hole.

(4) They allow the lubricant, when one is used, to flow easily down to the cutting edge of the drill.

The drill shank is the end that fits into the chuck of the hand drill. Figure 41 shows the two shapes of shank commonly used for hand drilling. The straight shank is generally used in hand, breast, and portable electric drills; the square (or bit) shank is made to fit into a brace.

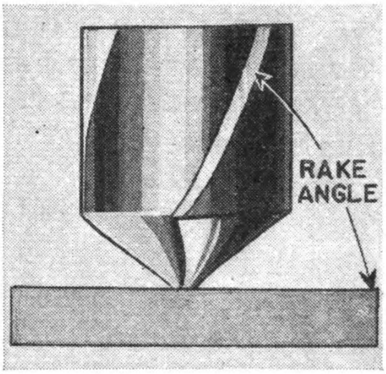

FIGURE 40.—Rake angle.

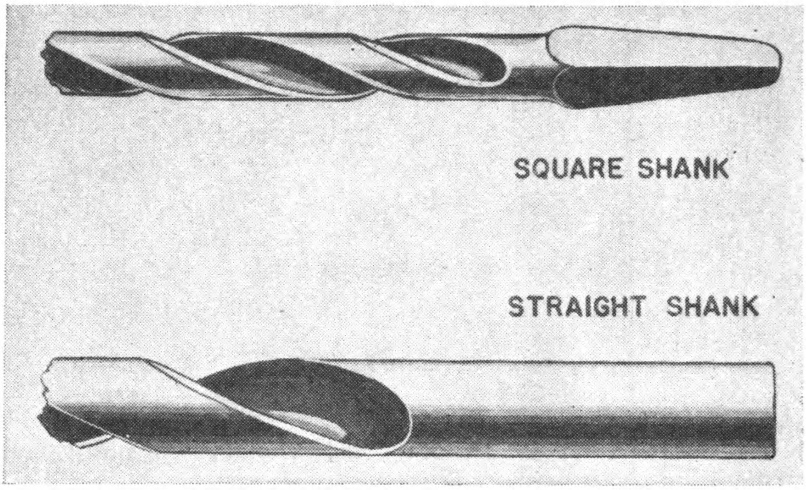

FIGURE 41.—Drill shanks for hand use.

b. Use of hand drills.—When drilling, some materials require no lubricant while others require a lubricant peculiar to their nature. The following table may be used as a guide:

Tool steel—oil.
Soft steel—oil or soda water.
Wrought iron—oil or soda water.
Cast iron—dry.
Brass—dry.
Copper—oil.
Babbitt—dry.
Glass—turpentine.

(1) *Brace.*—In rotating a twist drill by hand with a brace (fig. 38), the following procedure will give satisfactory results:

(*a*) Locate the *exact* position of the hole by drawing two lines on the work at right angles, so that they cross each other at the point to be the center of the hole. Make a light mark with a prick punch where the lines intersect. Check to make sure the prick punch mark is located *exactly* where the lines cross. Then sink it deep enough with a center punch to receive the chisel point of the drill. Select a *sharp*, properly ground square shank drill of the desired size, insert the shank in the jaws of a ratchet brace, and fasten it tightly in position. Grip the work firmly in a vise unless it is stationary; drilling is usually done horizontally, especially when considerable pressure is required. Put a drop of oil into the impression made by the center punch. Set the rachet on the brace so that the drill will turn clockwise, which is forward. Place the point of the drill into the center punch impression and begin drilling, being sure to keep the drill at right angles to the surface of the work throughout the operation. Keep a steady, firm pressure on the head of the brace.

(*b*) When the drill has started to cut and has made an impression larger than the center punch mark, lift it from the work, and see that the impression is concentric with the cross lines. If it is not, make a nick in the impression with a roundnose chisel on the side of the center toward which the drill should be drawn, as shown in figure 42. This operation must be performed before the drill point has completed its purpose.

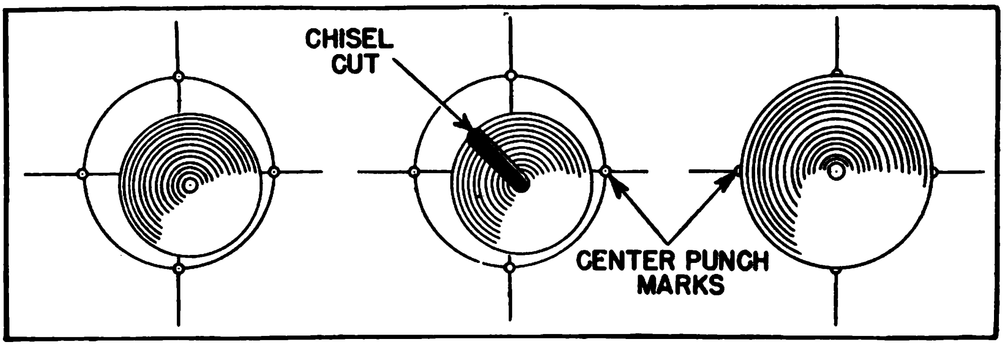

FIGURE 42.—How to draw back drill to correct center.

(*c*) Put another drop of oil into the impression and continue drilling until the point of the drill just breaks through the metal. Then ease the pressure on the brace and drill slowly until the hole is completed. If the drill catches while finishing the hole, put the ratchet of the brace in neutral position and work the drill back and forth carefully until it cuts through the work.

(2) *Using hand or breast drill.*—In using the hand or breast drill, the procedure should be generally the same as when using a brace, except that a straight shank drill must be selected. To apply pressure to the breast drill, the usual procedure is for the operator to push against the end of the tool with his body.

(3) *Pilot holes.*—The capacity of most hand drills is 1/4 inch, and when drilling in hard material the mechanic may find that when the size of the hole approaches this maximum, it may be very difficult to force the twist drill into the work. In such cases, it is good practice to drill a pilot hole first, about half the size of the diameter desired or a little less, and then follow this pilot hole with a drill of the final diameter.

(4) *Testing depth.*—When a hole is to be drilled only part way through the work, the depth can be measured approximately by inserting a piece of dowel rod, a pencil, or the stem of a match into the hole, and then measuring the length of the inserted part. If extreme accuracy is required, a depth gage should be used.

12. Grinding and sharpening drills.—*a. General.*—Before any drill is used on any kind of work, it is very important that it be correctly ground and sharpened. The automotive mechanic should understand the method of doing this, because unless the drill is in proper condition for work it will almost certainly make a hole that is rough or off size and perhaps break while in use. The mechanic should become familiar with the various parts of the drill shown in figure 39 so that he can understand clearly the work of grinding and sharpening.

b. Parts of the drill.—The parts involved in grinding drills are as follows:

(1) *Dead center.*—The dead center is the sharp chisel edge at the extreme tip end of the drill. It is formed by the intersection of the cone-shaped surfaces of the point and should always be in the exact center of the drill's axis.

(2) *Point.*—The point of a drill is the *entire* cone-shaped surface at the cutting end. It should not be confused with the dead center.

(3) *Heel.*—The heel of a drill is the portion of the point back of the lips or cutting edges.

(4) *Lip clearance angle.*—The lip clearance angle is the angle at which the drill point is ground off just back of the lips.

(5) *Margin.*—The margin is the narrow strip, shown in figure 39, which extends the whole length of the flutes and is practically the full diameter of the drill. Actually, the margin is part of a cylinder that is interrupted by the flutes and by what is known as body clearance.

(6) *Body clearance.*—The portion of the drill back of the margin, shown in figure 39, is of slightly less diameter than the margin, and the difference is known as body clearance. This clearance reduces the friction between the drill and the walls of the hole, while the margin insures the hole's being the right size.

(7) *Web.*—The web (fig. 43), is the metal column which separates the flutes. It runs the entire length of the drill between the flutes, gradually increasing in thickness toward the shank.

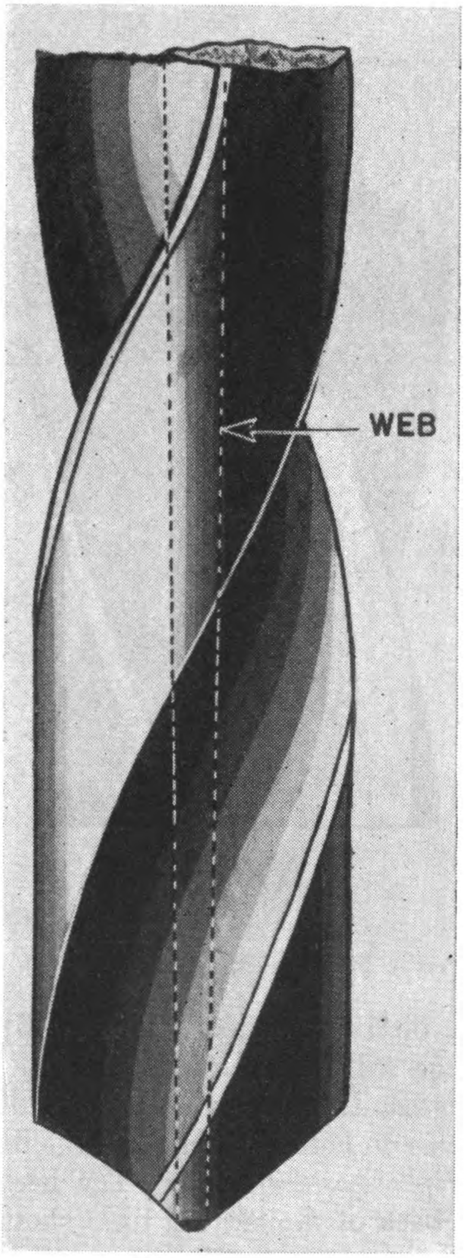

FIGURE 43.—Drill web.

c. Grinding the lips or cutting edges.—It has been learned by experience that for work on steel or cast iron, the lips of a twist drill should be the same length and ground to a 59° angle, as shown in figure 44. If the angle is more than 59° the point will be too flat to center properly; if less than 59° the hole will be drilled less rapidly than it should be, and more power will be required to drive the drill. If the point is on center but the cutting edges ground at different

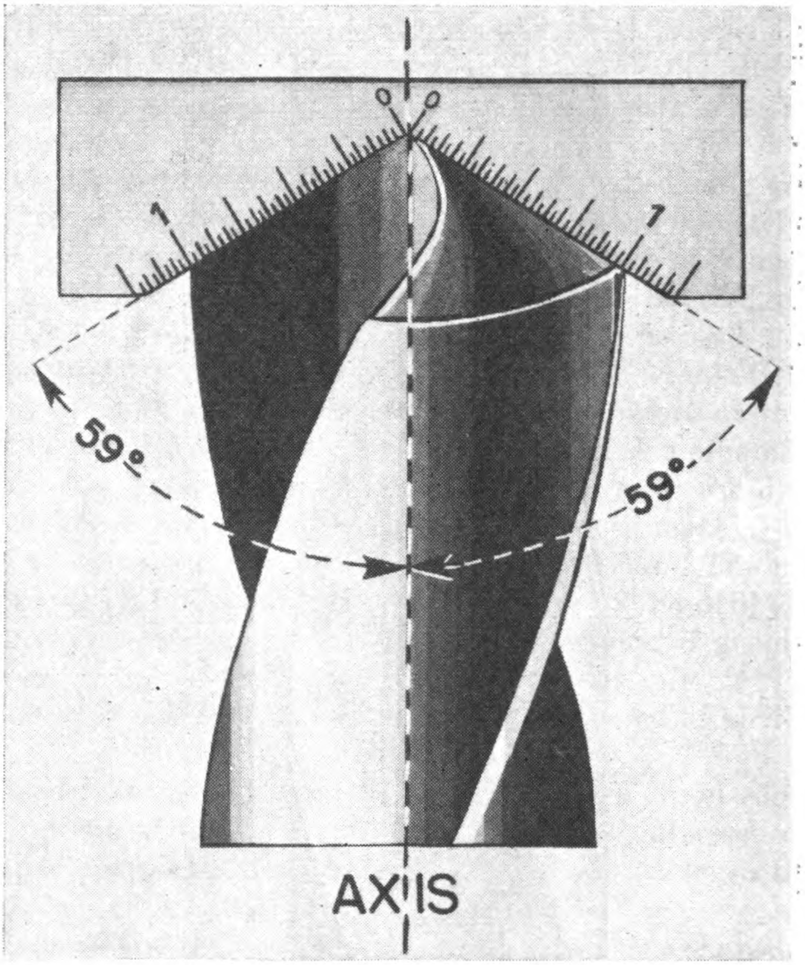

FIGURE 44.—Correctly ground drill lips.

angles, the drill will bind on one side (see fig. 45), only one lip will do the work, that edge will wear rapidly, and the hole will be larger than the drill. This condition should be carefully avoided because of the strain it imposes on both the drill and the tool used to rotate it.

d. Grinding the lip clearance angle.—The heel of the drill (the surface of the point back of the cutting lips) should be ground away from the cutting lips at an angle of from 12° to 15° at the circum-

ference of the drill, as shown at the right in figure 45. The results of incorrect lip clearance grinding are shown in figure 46. The drill on the left has been ground without any lip clearance whatever; in the center example, the lip clearance angle is so large that the cutting edges of the drill have broken down because of insufficient support; the illustration on the right shows the results of grinding the lip clearance angle too small. In this case, the drill ceased to have any

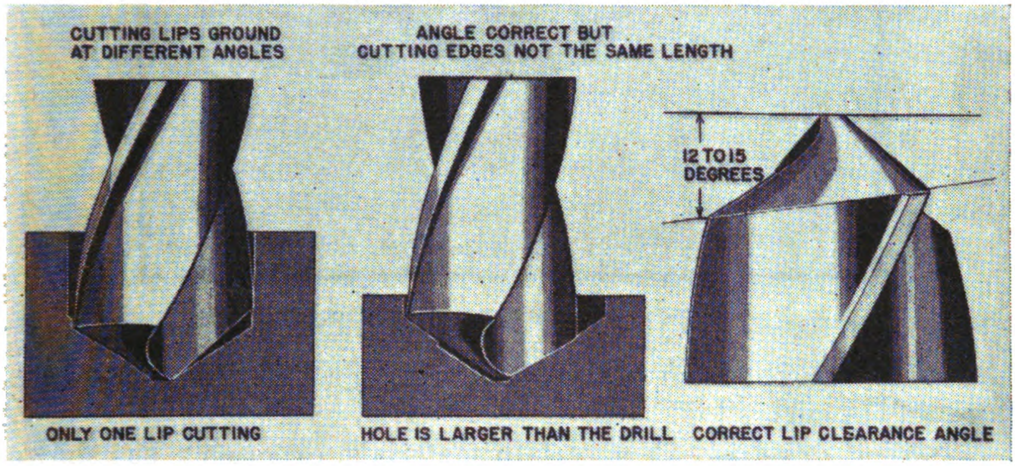

FIGURE 45.—Results of incorrect lip grinding.

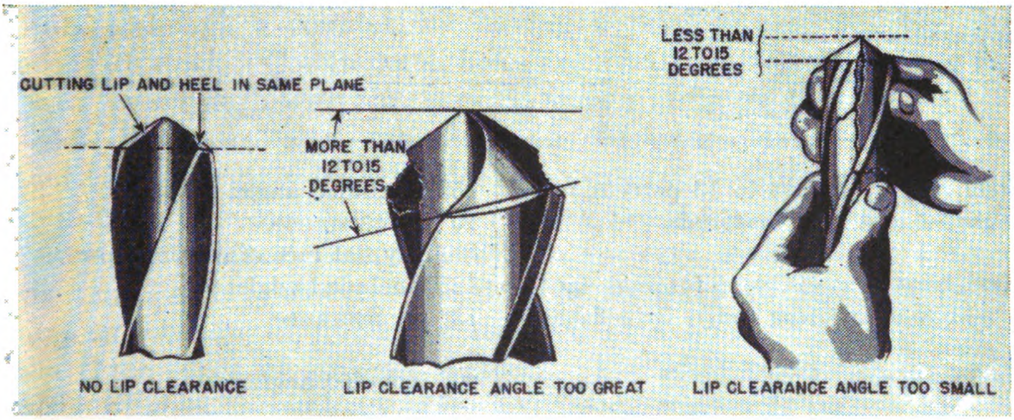

FIGURE 46.—Results of incorrect lip clearance grinding.

cutting edges whatever, and the pressure used to feed it into the hole split it up the center.

e. Rake angle.—The rake angle of a drill is the angle of the flutes in relation to the work, as shown in figure 40. It is usually between 22° and 30°. If this angle is too small, it makes the cutting edge so thin it may break under the strain of the work. The rake angle also partly governs the tightness with which the chips curl, and hence the amount of space they occupy. Figure 47 shows how chips

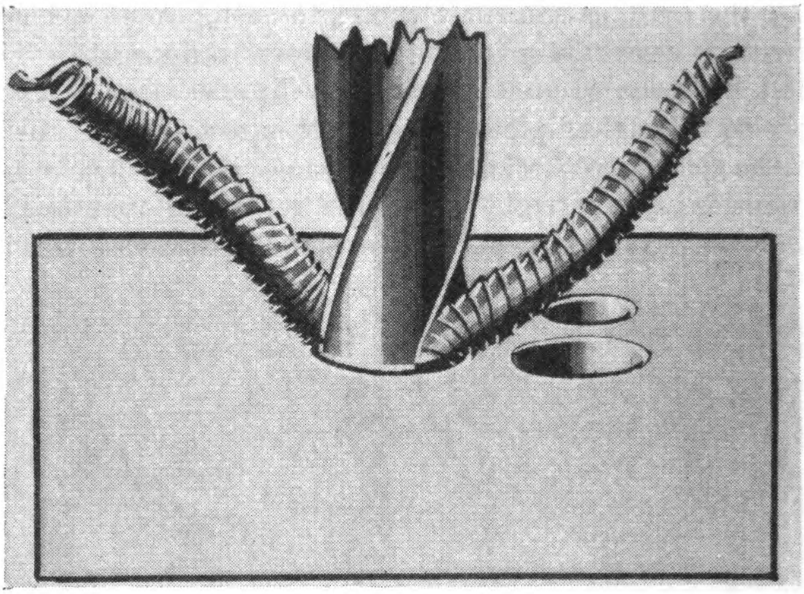

FIGURE 47.—Correct curl of chips.

curl when removed from steel by a correctly ground drill. Cast iron chips do not curl.

f. Special grinding.—For certain materials, experience has shown that twist drills should be ground with special lip and lip clearance angles. The following table outlines recommended angles for special materials:

Material	Point
Steel rails 7 percent to 13 percent manganese and hard materials.	150° included angle. 10° lip clearance. Slightly flat face of cutting lips.
Heat-treated steels, drop forgings (automobile connecting rods), Brinell hardness No. 250.	125° included angle. 12° lip clearance.
Cast iron, soft	90° included angle. 12° lip clearance.
Brass	118° included angle. 12° lip clearance. Slightly flat face of cutting lips.
Wood	60° included angle. 12° lip clearance.
Hard rubber; bakelite; fiber	60° and 90° included angle.
Copper	100° included angle. 12° lip clearance.
Crankshafts	118° included angle. Chisel point.

g. Drilling in glass.—The usual method of drilling holes through glass is to use a tube of soft metal, generally brass, with an outside diameter the same as that of the desired hole. The tube is used as a drill, except that an abrasive, such as carborundum mixed with water or light oil, must be applied to the work while drilling, and light pressure used. A dam of putty is usually placed around the spot to be drilled to retain the abrasive mixture. Notches can be filed into the end of the metal tube to hold the abrasive and make the operation faster. The best practice is to place the glass on a yielding support such as a felt or rubber pad; drill the hole halfway through the glass, then turn the work over and complete the operation from the opposite side.

13. Counterboring and countersinking.—The mechanic often finds it necessary to enlarge a hole for part of its depth so that the head of a screw run into it will be flush with the surface of the work. The tools used for this operation are counterbores and countersinks, shown in figure 48. The counterbore is fitted with a guide or pilot which fits into the hole and thus keeps the diameter of the enlarged section on the same center as that of the original hole. Figure 48 illustrates how a fillister head machine screw fits into a counterbored hole. When a hole is countersunk, the enlarged portion is shaped like a section of a cone; no pilot is necessary on a countersink, although a countersink having a pilot is used for the most accurate work. Countersunk holes are usually intended to bring flathead screws flush with the work, as shown in figure 48.

14. Reamers and reaming.—*a. General.*—Hand reamers are tools for enlarging drilled holes to an exact size while finishing them round, straight, and smooth. The two types in general use are straight reamers and taper reamers, and both are very useful to the automotive mechanic whenever considerable accuracy of size, roundness, and smoothness of finish are required of a hole. Figure 49 shows the three types of straight reamers. The solid reamer is one solid piece of steel throughout. The expansion reamer is hollow and has longitudinal cuts in some of its flutes; by means of a tapered screw plug, its diameter can be expanded a few thousandths of an inch. Solid and expansion reamers are made with straight and spiral flutes. The cutting edges or lands between the flutes are usually regularly spaced. However, some solid reamers have irregularly spaced lands to avoid "chatter," which causes roughness in the finish of the work. The blades of the adjustable reamer are separate from the body and are fitted into grooves in the shank of the tool which is threaded. Adjusting nuts fit on these threads and, when turned back and forth, move

the blades along the tapered grooves, thus increasing or decreasing the diameter of the reamer. It is advisable to use a solid reamer for most work because it is the most accurate and rugged of the straight reamers. If too much metal is removed with a taper, expansion, or

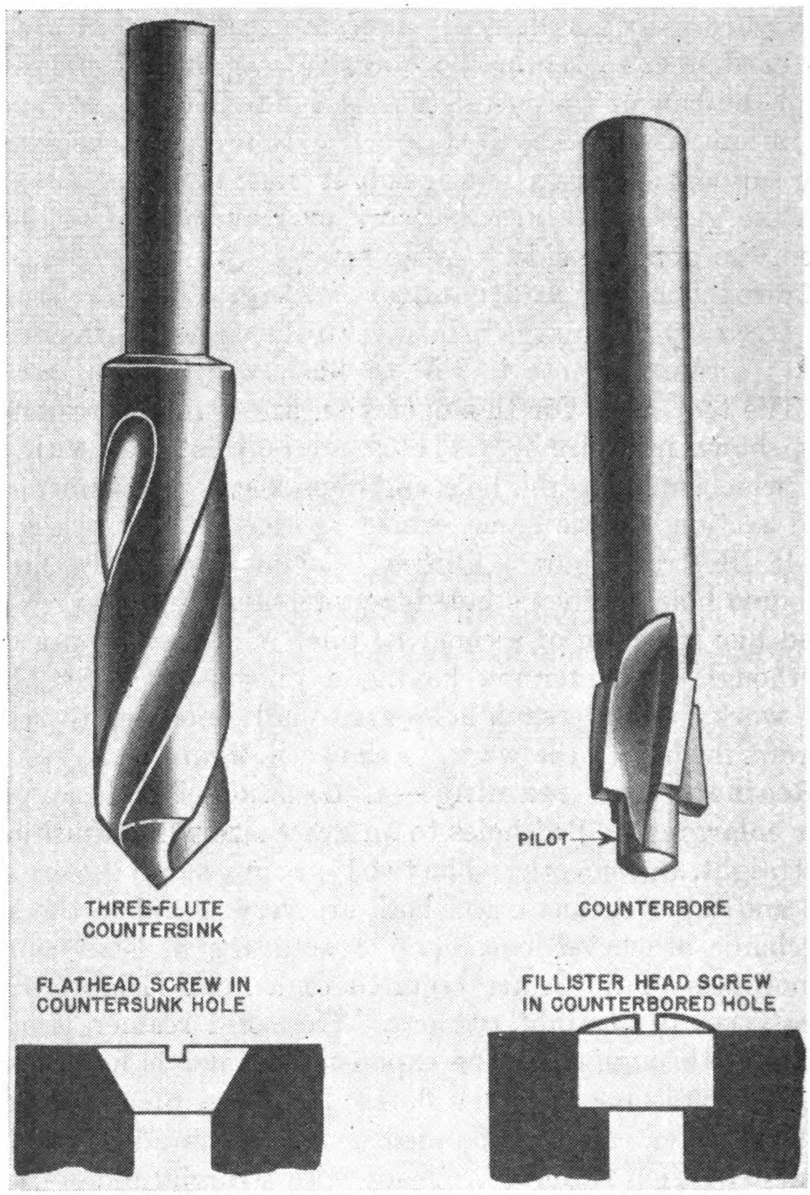

FIGURE 48.—Counterbore and countersink.

adjustable reamer, the work is usually ruined; the operator should therefore take a series of small cuts rather than one deep one when using them, testing the hole frequently for size. Small reamers should not be forced into a hole with too much pressure because they

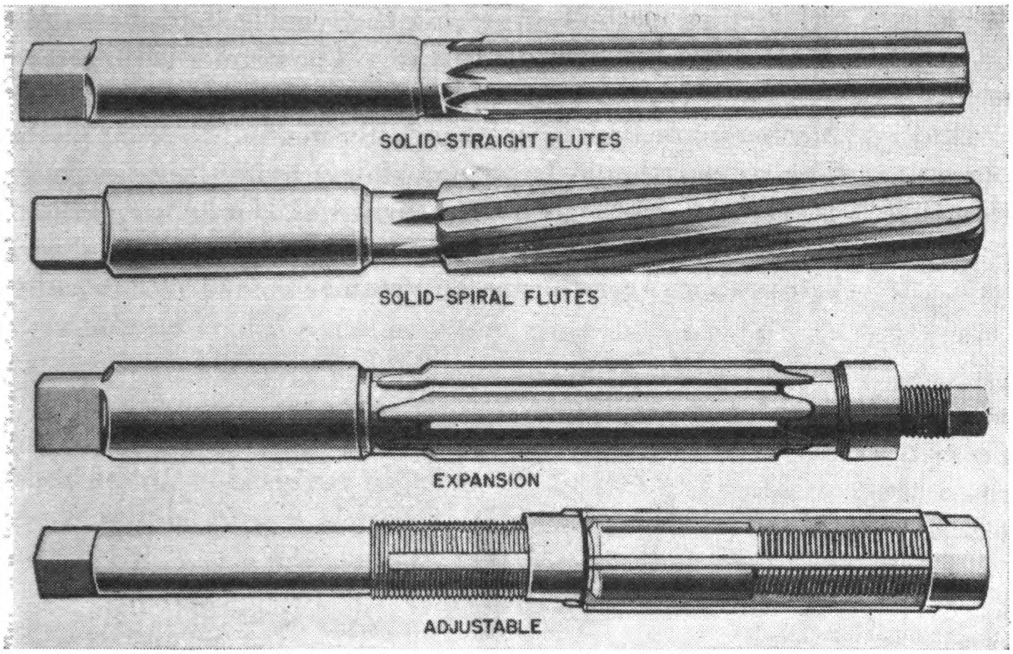

FIGURE 49.—Types of straight reamers.

are delicate and easily broken. Figure 50 shows a taper reamer and a taper pin to fit in the hole finished by it. A valve reseating tool is a special kind of tapered reamer. When two or more holes in line with one another must be reamed, a special alining reamer having a pilot (or guide) must be used.

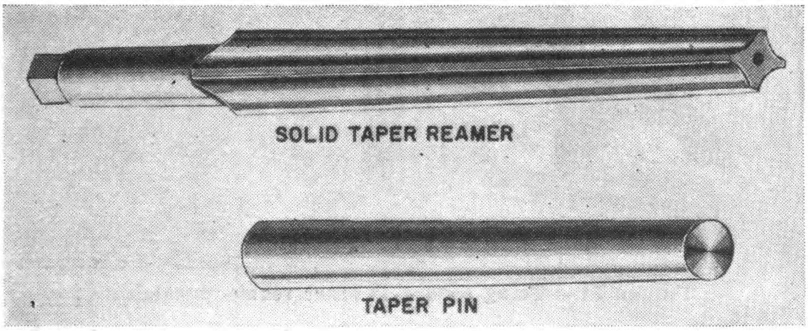

FIGURE 50.—Taper reamer and pin.

b. Use of straight reamers.—The most important factor in the use of straight hand reamers is to have the hole the correct size to begin with, and then to be sure the reamer is started straight in the hole. Hand reamers are intended to remove only 0.002 to 0.003 (thousandths) inch of metal. Straight reamers have a slight taper starting ¼ to ¾ inch from the end so that they will start into the hole easily. Figure

51 shows a satisfactory method of getting the reamer started straight by checking it from two sides with a square. The reamer is turned by means of a wrench, or it can be set up in a vise and the work turned around it. Mechanics ordinarily use the latter method to ream piston pin holes. The reamer should be turned slowly until the operator is *sure* that it is straight in the hole, then turned *clockwise only* with a steady, firm pressure until it has been put all the way through the hole. It is bad practice ever to turn any reamer counterclockwise; it

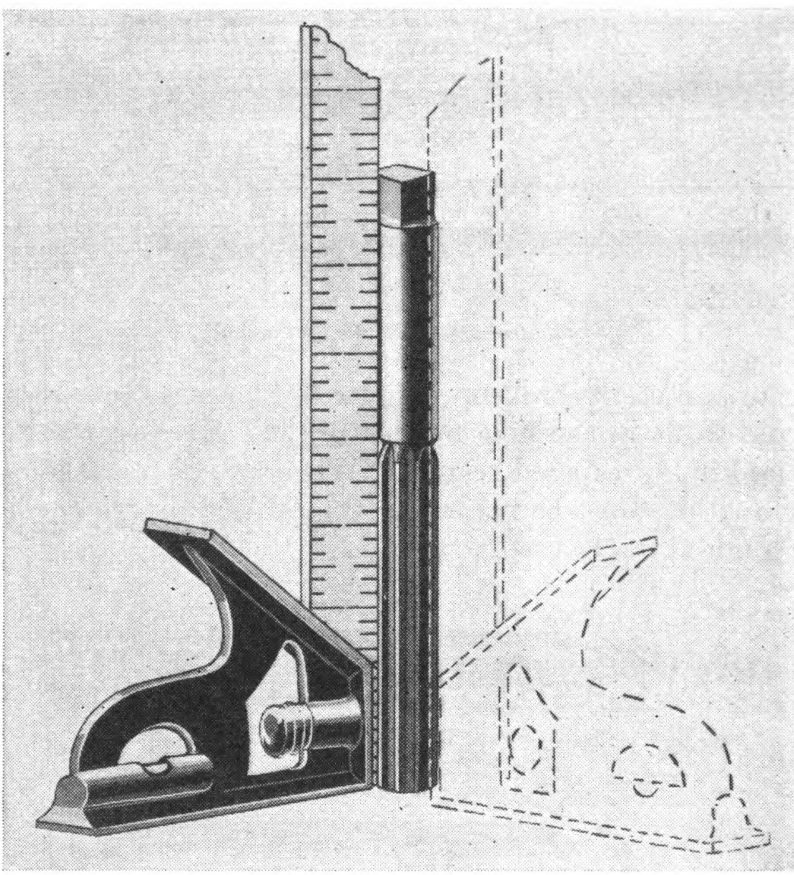

FIGURE 51.—Using square to start reamer straight.

will not only fail to cut when so turned but will quickly become dull and useless. When reaming steel, cutting oil or ordinary machine oil should be used to lubricate the tool; cast iron, especially if soft, should be reamed dry. Feeding (applying pressure to) the reamer too fast or too slowly will cause chattering which will make the hole uneven.

c. Use of taper reamers.—As the name indicates, taper reamers are used to finish tapered holes for the insertion of tapered pins or other tapered parts. They are made with a standard taper of 1/4 inch

per foot, in various sizes so arranged that each overlaps the next smaller size by about ½ inch. It is very important in using taper reamers that the hole be the right size, generally just large enough to allow about ½ inch of the reamer's length to go into it. Since taper reamers must remove a considerable amount of metal, the drill used for making the hole should be the largest possible size that will allow the reamer to clean up the hole *along its entire depth.* In most shops a table similar to table I is available and should be used as a guide. If it is not, no choice remains except the "cut and try" method, taking extreme care not to ream the hole too large or too deep. In starting the taper reamer, keep it as nearly straight as possible with the hole; most mechanics judge this straightness by eye, and practice makes a high degree of accuracy possible. Like straight reamers, taper reamers should be turned *clockwise only,* with firm, steady pressure. Remember that it is a tool easily broken.

TABLE I.—*Taper reamers and pins*

Size	Diameter of small end of reamer (inches)	Diameter of large end of reamer (inches)	Length of flute (inches)	Total length of reamer (inches)	Size drill for reamer (inches)	Longest limit length of pin (inches)	Diameter of large end of pin (inches)	Approximate fractional size at large end of pin (inches)
0	0.135	0.162	1 5/16	2	28	1	0.156	5/32
1	.146	.179	1 9/16	2 3/8	25	1 1/4	.172	11/64
2	.162	.200	1 13/16	2 11/16	19	1 1/2	.193	3/16
3	.183	.226	2 1/16	3	12	1 3/4	.219	7/32
4	.208	.257	2 3/8	3 7/16	3	2	.250	1/4
5	.240	.300	2 7/8	4 1/8	1/4	2 1/4	.289	19/64
6	.279	.354	3 5/8	5	9/32	3 1/4	.341	11/32
7	.331	.423	4 7/16	6 1/16	11/32	3 3/4	.409	13/32
8	.398	.507	5 1/4	7 1/16	13/32	4 1/2	.492	1/2
9	.492	.609	6 1/8	8 1/8	31/64	5 1/4	.591	19/32
10	.581	.727	7	9 1/2	19/32	6	.706	23/32
11	.706	.878	8 1/4	11 1/4	23/32	7 1/4	.857	55/64
12	.842	1.050	10	13 3/8	55/64	8 3/4	1.013	1 1/64
13	1.009	1.259	12	16	1 1/64	10 3/4	1.233	1 15/64

Taper equals one-fourth inch per foot or 0.0208 inch per inch.
These reamer sizes are so proportioned that each overlaps the size smaller about ½ inch.

d. Care of reamers.—Never turn a reamer any way except to the right or clockwise even when removing it from the work. Do not use too much feed (pressure) because the reamer may hit a hard spot in the metal and break. This is especially likely with small-sized reamers. When using a lubricant on the reamer, it is good

practice to remove the tool from the work frequently and wipe away the chips which stick to the flutes; if they clog, they are likely to damage the finish on the walls of the hole. Do not expect a reamer to remove more than 0.002 to 0.003 inch of metal. If the hole is too small, enlarge it with a drill before reaming it. An adjustable reamer must be kept absolutely clean to do accurate work. Handle reamers carefully; if they are dropped or thrown against other tools, their sharp edges will be nicked and dulled.

e. Preventing chatter in reamers.—When a hand reamer chatters, even when fed with the proper pressure, it is generally a sign that it has not been sharpened correctly for the particular metal being reamed. When chattering occurs, replace the reamer being used with another one; if it isn't, the walls of the hole will be rough and work and time wasted. Resharpening reamers is usually a factory operation; the average mechanic should not attempt it. Only the largest, most complete tool rooms are equipped for this resharpening. Sometimes, if the edges of the reamer are only slightly dull, one can restore them by using a thin hone on the flutes, or if the reamer is adjustable, one can insert new blades in it; but it is almost always better to get a new tool if chattering occurs.

15. Threads, taps, and dies.—*a.* In assembly and disassembly operations on motor vehicles, threaded parts such as nuts, bolts, and screws are handled so frequently that every mechanic should be thoroughly familiar with their various types and uses and should understand the common methods of cutting or renewing threads.

b. The common devices used for fastening or holding metal parts together are bolts and nuts, screws, washers, and rivets.

(1) Figure 52 shows the various types of bolts in everyday use. They are generally suitable for holding pieces or parts together that

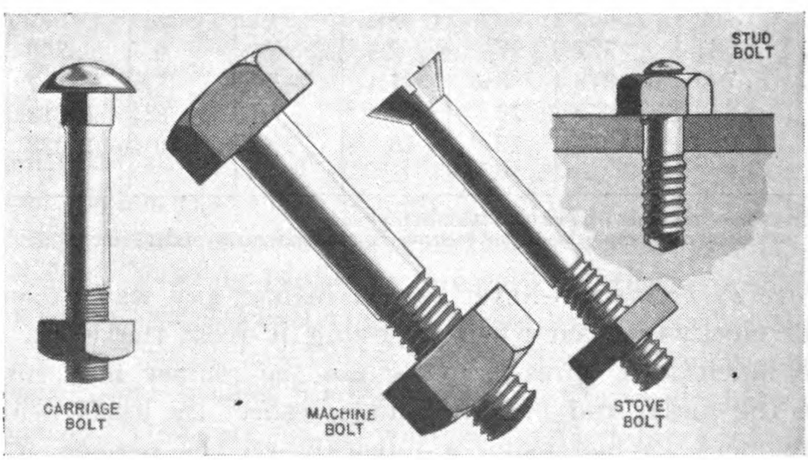

FIGURE 52.—Types of bolts.

on occasion must be removed or taken apart. They are always used with a suitable nut.

(2) The types of screws the mechanic ordinarily has to work with are shown in figure 53. Cap screws and machine screws are generally used without nuts. so a hole must be threaded (tapped) to receive

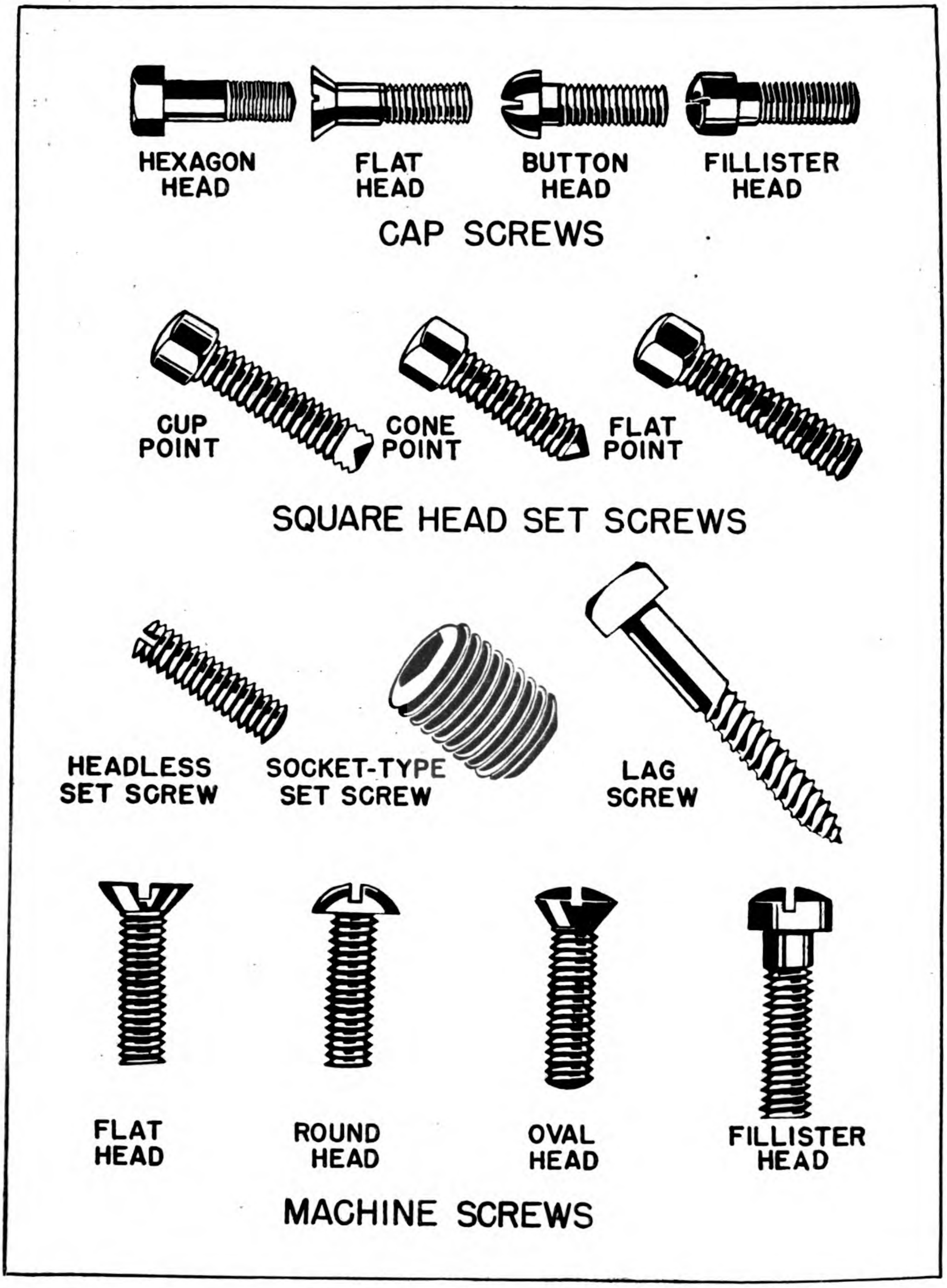

FIGURE 53.—Types of screws.

them. Cap screws have a rounded end which pilots the thread into the tapped hole. The flat end of a machine bolt is likely to "walk" before the threads catch. All types of machine screws are available with Phillips cross-slot heads, as shown in figure 5. Set screws are ordinarily used to set wheels or collars solidly on shafts. Socket-type set screws are turned by a small wrench made of a piece of hexagon rod bent and hardened. Lag screws are for holding metal to wood; they cut their own threads in undersized holes bored in the wood. Sheet metal screws, which are hardened and cut their own threads in drilled or punched holes, are used extensively in automotive body work.

(3) At times a screw or stud will break off in a hole and must be extracted. The best method of doing this is to use a screw extractor. First drill a hole in the broken screw or stud a little smaller than its body diameter; then insert the extractor into this hole and turn it counterclockwise. The screw extractor is tapered and has sharp ridges, similar to left-hand threads, which will grip the sides of the hole in the broken part so that it can be turned out of the hole by a wrench. The screw extractor and the method of using it are shown in figure 54.

(4) Rivets (fig. 55) although not threaded are classified as metal fasteners; the pressure of their heads, instead of threads, exerts holding force. They are very commonly used for permanent fastening but are not practical for any assembly that has to be taken apart.

(5) Nuts (fig. 56) must always be used with some kind of bolt or stud, so that the two pieces, nut and bolt or nut and stud, exert holding force by the strength of their threads. They are suited to assemblies that may have to be removed or taken apart. Wing nuts are especially useful where there is frequent occasion for hand adjustment. Castle nuts can be set immovable by a cotter pin placed through the slots provided in the nut and a hole in the bolt.

(6) Washers, also shown in figure 56, are often put under nuts or bolt heads to protect the pieces being fastened or to make tightening up easier. Lock washers are made of spring steel and exert a light bite on a nut to keep it from turning and becoming loose.

16. Threads.—Threads are helical ridges cut into screws, nuts, bolts, or the walls of a hole, so that the action of turning the screw, nut, or bolt gives it endwise as well as rotary motion. Although there are many types of threads, only two, National Coarse (NC) and National Fine (NF), are commonly used in motor vehicle work. NC threads range from 64 to 6 threads per inch, NF from 80 to 12 per inch. Any type of thread is either an outside (or male) thread, as

the threads on a bolt or screw, or an inside (or female) thread, as in a nut or inside a hole. In specifying or cutting threads two measurements must be known—the diameter and the pitch. Machine screws, for example, have their diameter indicated by a number, No. 0 being the smallest and No. 12 the largest; to this number is always added the number of threads per inch. For instance, suppose a screw is desig-

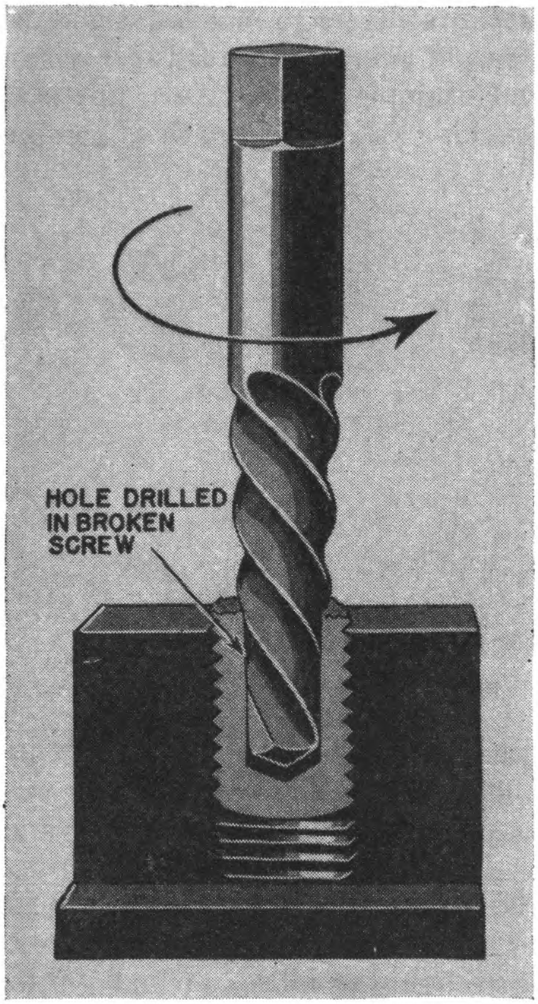

FIGURE 54.—Using screw extractor.

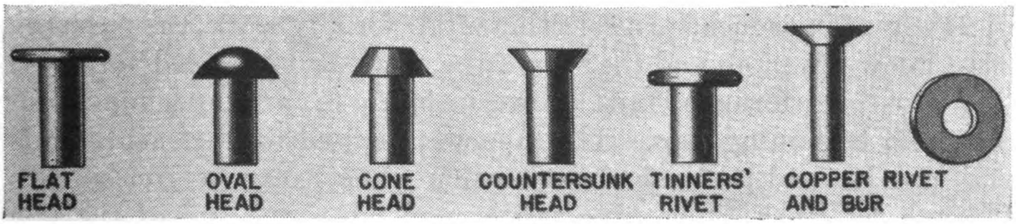

FIGURE 55.—Types of rivets.

nated as No. 10–24. The 10 specifies the diameter of the screw's body; the 24 means it has 24 threads per inch. A 10–30 screw would be the same diameter, but have 6 more threads in an inch of length. Larger-sized screws or bolts have their diameters indicated by actual measurement; for example, a 5/16 inch–24 screw is 5/16 inch in diameter and has 24 threads per inch of length; a 5/16 inch–18 screw has the same diameter but only 18 threads per inch of length. If a given set of male and female threads are to match (as for instance a nut and bolt), *both* their size and number of threads per inch must be the same. A No. 8–30 nut, for example, will *not* turn up on a No. 8–36 screw. In each of the foregoing cases, the length of the screw must also be specified.

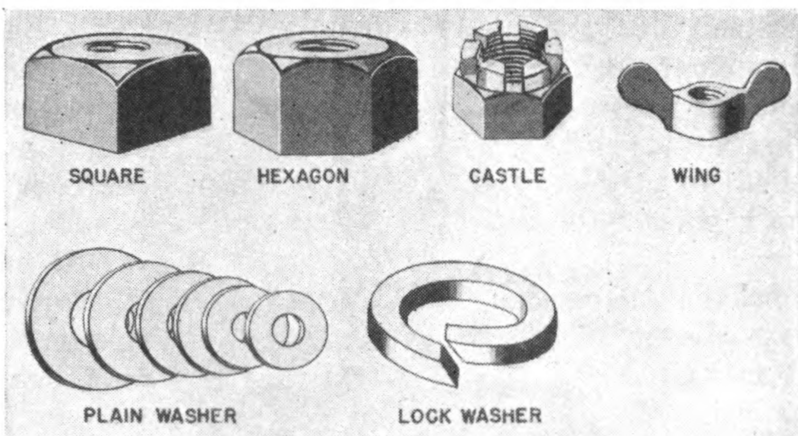

FIGURE 56.—Types of nuts and washers.

17. Use of taps.—*a.* Taps are tools used for cutting inside or female threads in holes in metal, fiber, or other material. The two kinds in common use are standard hand taps and machine screw taps.

b. Standard hand taps are made for cutting threads from 1/16 of an inch up to 4 inches in diameter; machine screw tap diameters are designated by numbers ranging from No. 0 (smallest) to No. 30 (largest) to fit the corresponding sizes of machine screws. Thus a 10–24 tap will thread a hole or nut properly for a No. 10 screw having a pitch of 24 threads per inch. In selecting a tap for any work, the mechanic *must* know the pitch and the size of the screw being tapped for.

c. The three forms of taps, shown in figure 57, are taper taps, plug taps, and bottoming taps. The taper tap is used to start all threads, and may be used to finish the operation when it can be run entirely through the work. The plug tap is used when one end of the hole

is closed. The bottoming tap is used when it is necessary to cut a full thread to the bottom of a closed hole. Plug taps or bottoming taps should *never* be used to start a thread.

TABLE II.—*Screw thread sizes*

Nominal size	Outside diameter (inches)	Pitch diameter (inches)	Root diameter (inches)	Commercial tap drill to produce approximately 75 percent full thread	Decimal equivalent of tap drill
0-80-F	0.0600	0.0519	0.0438	3/64	0.0469
1-56	.0730	.0614	.0498	54	.0550
64-C	.0730	.0629	.0527	53	.0595
72-F	.0730	.0640	.0550	53	.0595
2-56-C	.0860	.0744	.0628	50	.0700
64-F	.0860	.0759	.0657	50	.0700
3-48-C	.0990	.0855	.0719	47	.0785
56-F	.0990	.0874	.0758	45	.0820
4-32	.1120	.0917	.0714	45	.0820
36	.1120	.0940	.0759	44	.0860
40-C	.1120	.0958	.0795	43	.0890
48-F	.1120	.0985	.0849	42	.0935
5-36	.1250	.1078	.0889	40	.0980
40-C	.1250	.1088	.0925	38	.1015
44-F	.1250	.1102	.0955	37	.1040
6-32-C	.1380	.1177	.0974	36	.1065
36	.1380	.1200	.1019	34	.1110
40-F	.1380	.1218	.1055	33	.1130
7-30	.1510	.1294	.1077	31	.1200
32	.1510	.1307	.1104	31	.1200
36	.1510	.1330	.1149	1/8	.1250
8-30	.1640	.1423	.1207	30	.1285
32-C	.1640	.1437	.1234	29	.1360
36-F	.1640	.1460	.1279	29	.1360
40	.1640	.1478	.1315	28	.1405
9-24	.1770	.1499	.1229	29	.1360
30	.1770	.1553	.1337	27	.1440
32	.1770	.1567	.1364	26	.1470
10-24-C	.1900	.1629	.1359	25	.1495
28	.1900	.1668	.1436	23	.1540
30	.1900	.1684	.1467	22	.1570
32-F	.1900	.1697	.1494	21	.1590
12-24-C	.2160	.1889	.1619	16	.1770
28-F	.2160	.1928	.1696	14	.1820
32	.2160	.1957	.1754	13	.1850

NOTE.—*C* equals coarse thread standard; *F* equals fine thread standard.

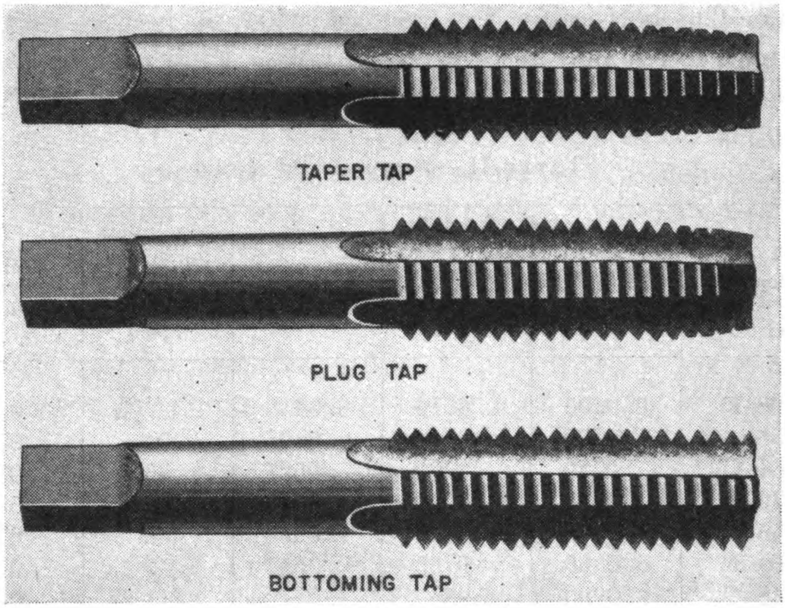

FIGURE 57.—Taps.

d. In order that there may be enough metal in the hole to provide material into which the threads can be cut, the hole must be slightly smaller to begin with than the full diameter of the screw to be used in it. Tables similar to table II are available in most places where tapping is done. Since it is important that the mechanic drill a hole the right size for the tap he is going to use, he should understand this type of table thoroughly and refer to it whenever possible. For example, if it is desired to tap a hole for a No. 12–24 screw, first find this size in column 1. Across from it in column 5 is shown the right size of drill to use. Hence for a No. 12–24 screw, the mechanic would drill the hole with a No. 16 tap drill; for a No. 10–28 screw, with a No. 23 tap drill; and so on. When any doubt exists as to the pitch of a screw, a screw pitch gage (fig. 58), if available, can be used. If a nut to fit the screw is at hand, it will serve the purpose of a pitch gage; try running it on the tap, and if it fits, the pitch of the tap is correct.

e. In the absence of a table, the following formula will give the approximately correct size of hole to drill for tapping:

$$\text{NC threads} - \text{tap drill} = \text{diameter} - \frac{1.3 \times \text{percent of thread wanted}}{\text{Number of threads per inch}}$$

$$\text{NF threads} - \text{tap drill} = \text{diameter} - \frac{1.4 \times \text{percent of thread wanted}}{\text{Number of threads per inch}}$$

NOTE.—Commercial practice uses 75 percent of a full thread, which is only 5 percent less efficient than a full depth thread.

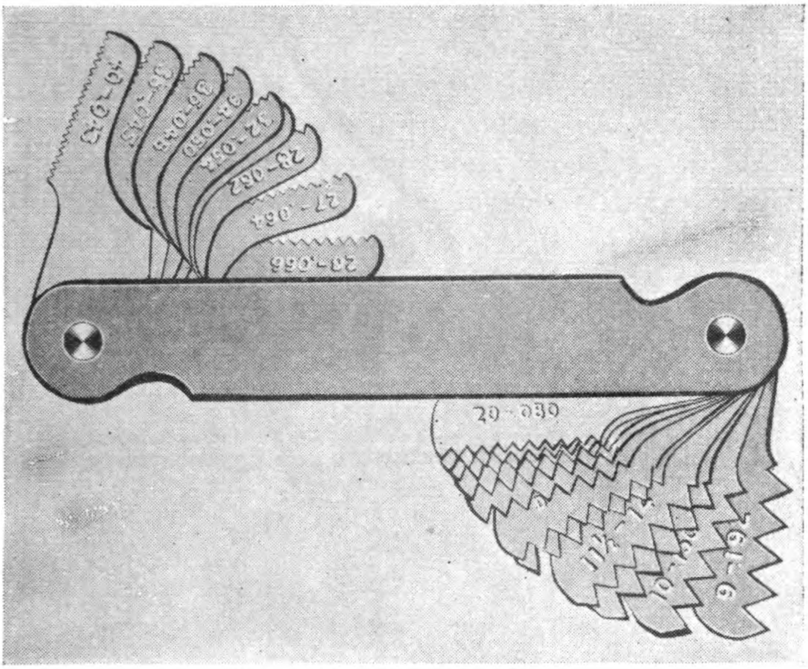

FIGURE 58.—Screw pitch gage.

18. Tapping.—*a.* When cutting female threads, a tap wrench is used to turn the tap. Figure 59 shows the best way to hold the wrench and tap when starting the operation. It is very important to start the tap straight and keep it so throughout the work, because taps, especially small ones, will almost surely break if bent or strained. The tap is not fed into the hole with any pressure; its threads will pull it in at the proper rate. When tapping steel, or any tough metal, the safest procedure is to take a half turn forward (clockwise), then a quarter turn back (counterclockwise), then a half turn forward, and so on until the work is completed. If the metal is soft, as cast iron or brass, the back turns are not necessary. When tapping steel or bronze, the tap should be well lubricated with lard oil; cast iron is drilled, tapped, and reamed dry; soft metals, such as brass, can be tapped dry. If the hole does not go clear through the work, *tap it first with a taper tap*, then use a plug tap, and finally follow with a bottoming tap if the hole must be threaded to its extreme end. Larger-sized taps are turned with an adjustable tap wrench of the type shown in figure 60. Some small taps up to 3/8 of an inch have large shanks which should not be turned beyond the surface of the work being tapped, as these shanks exert a reaming action which will cut out the threads.

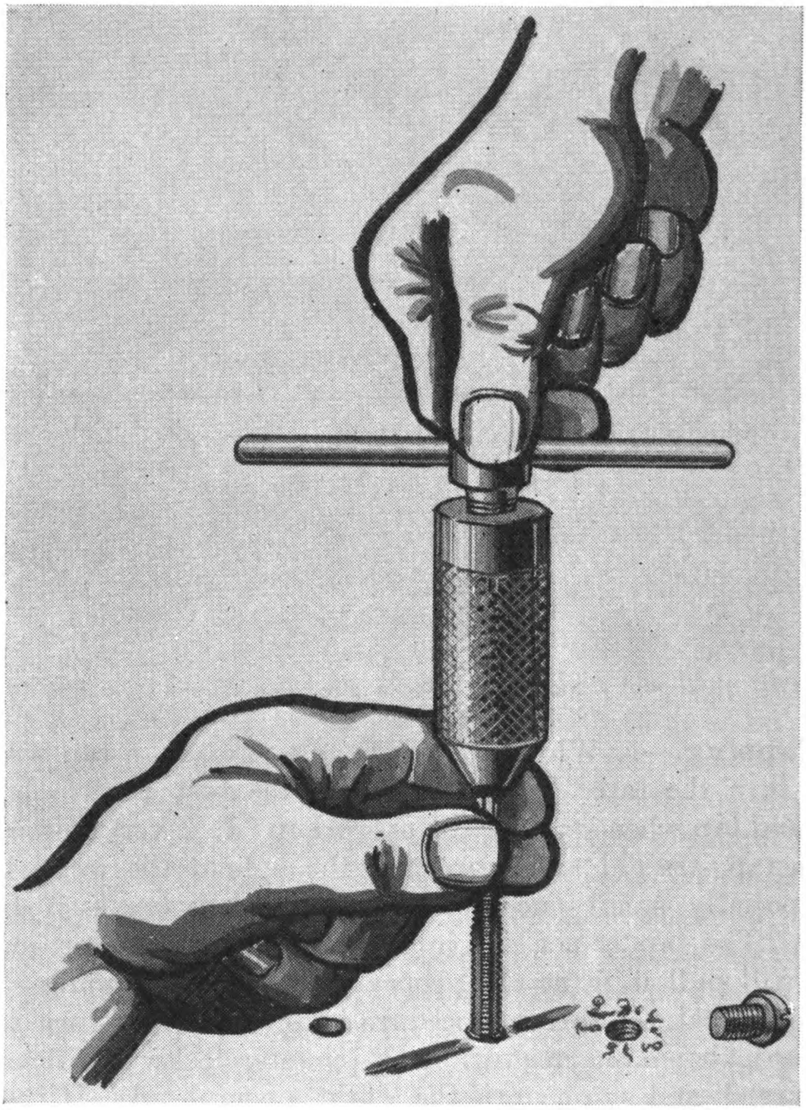

FIGURE 59.—Correct way to start tapping operation.

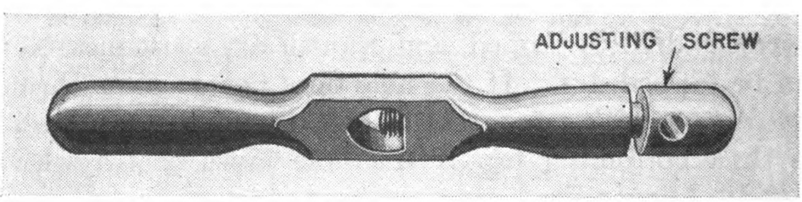

FIGURE 60.—Adjustable double end tap wrench.

b. Removing broken taps.—Even when used with care, taps will sometimes break off, and the mechanic should become familiar with the usual methods of removing the broken part of the tap from the hole. Two satisfactory ways of doing this are as follows:

(1) *Chisel or punch.*—Broken taps can often be removed by using a small, blunt cold chisel or a taper punch, as shown in figure 61. This will frequently start the tap; the job can be completed with a tap extractor as described below. Taps often shatter when they break; if this happens, the broken pieces should be picked from the hole with a small prick punch or a magnetized scriber before any attempt is made to remove the tap.

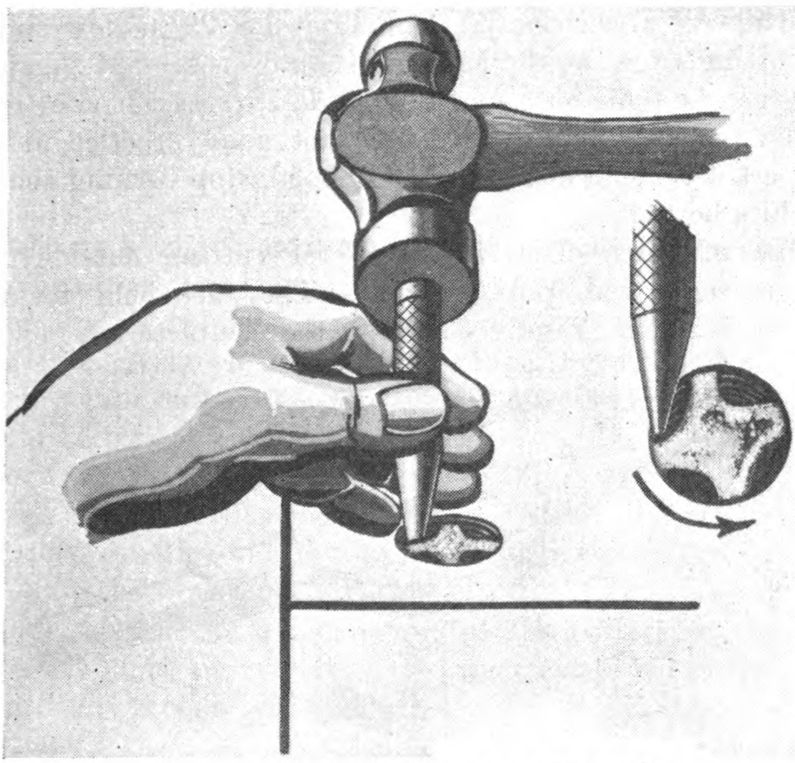

FIGURE 61.—Removing broken tap with punch.

(2) *Tap extractor.*—Figure 62 shows the application of a tap extractor. This tool has movable fingers which can be placed in the flutes of the broken tap, as shown, after which the collar should

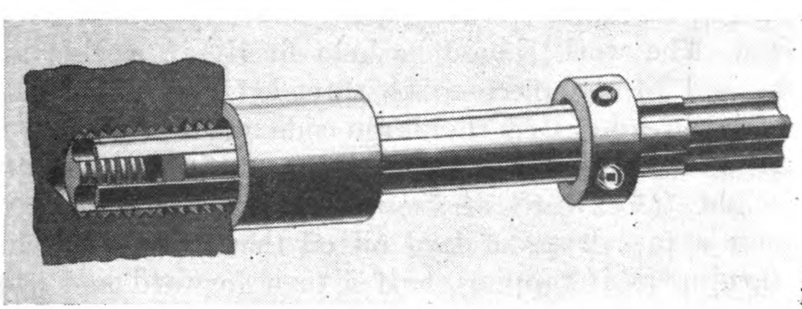

FIGURE 62.—Use of tap extractor.

be brought up against the surface of the work. A tap wrench can then be used on the extractor to back out the broken piece. The tap extractor will not stand much turning force without breaking the movable fingers. Removing a broken tap by any method is often a long, tedious job which requires time, skill, and patience. It is therefore wise for the mechanic to avoid breakage by being as careful as possible.

c. General precautions.—Be sure the tap used is sharp, because if it is dull it will break easily. Dull taps show a narrow shiny face on the cutting edges at the end and should be ground sharp. This grinding can be done on a machine made for the purpose; grinding by hand on a small emery wheel is not good practice unless one is an expert. When a closed hole is tapped, stop turning the instant the tap hits bottom.

19. Use of dies.—Dies are used for cutting outside or male threads, as on a rod, pipe, or bolt. They are held for turning leverage in a stock. Figure 63 shows the complete assembly ready

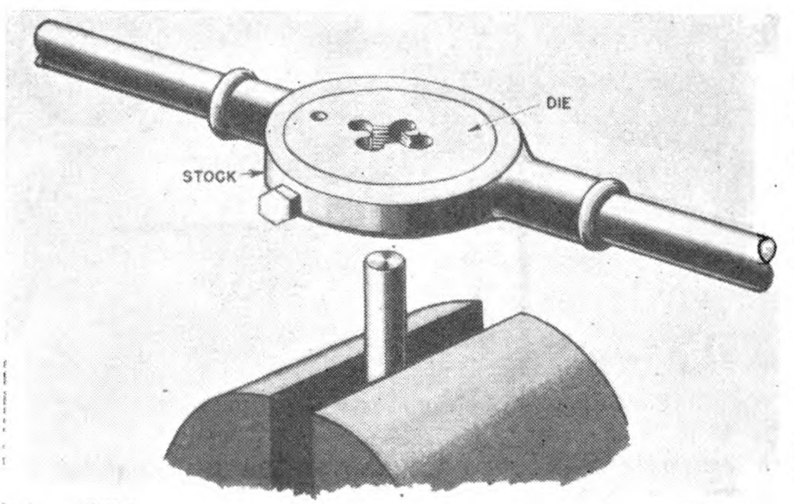

FIGURE 63.—Stock and die ready for use.

for use. The procedure for using dies correctly is similar to that for tapping. The work should be held firmly in a vise, and any bur on the end of the piece to be threaded removed with a file. To start the thread, place the large side of the opening in the die over the work and press down on the stock firmly, while turning it to the right (clockwise) as shown in figure 64. When the die catches, pour a few drops of lard oil on the end of the work and continue turning as if tapping, half a turn forward and a quarter turn back, until the thread is cut to the length desired. It is im-

portant that oil be kept on the work during the operation and, when finished, any chips of metal sticking to the die must be cleaned out.

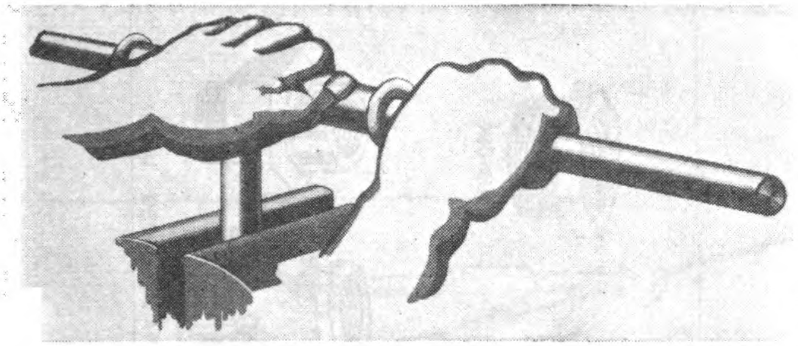

FIGURE 64.—Starting die.

20. Cutting and threading pipe.—*a. General.*—The automotive mechanic is often called on to cut, thread, and fit together various lengths of pipe, and should have some familiarity with the commonly used pipe fittings shown in figure 65. Pipe can be cut with a hacksaw, but if a pipe cutter (fig. 66) is available, it is more satisfactory and should be used.

b. Operating pipe cutter.—Mark the location of the cut clearly on the pipe with a scriber, soapstone, or chalk. In measuring pipe it is the usual practice to allow ½ inch in length for thread to enter fitting. Grip the work in a pipe vise and slip the cutter over the end of the pipe. By turning the handle of the cutter, set the cutting wheels on the mark previously made; then rotate the cutter, setting up the cutting wheels after each complete turn by turning the handle clockwise until the pipe is separated. Keep the cutter perpendicular to the work at all times or the wheels will not track properly. Remove the bur which is left inside the pipe with a pipe reamer (fig. 67).

c. Cutting pipe threads.—Pipe fittings have tapered threads and require special dies, called pipe dies, so they can be turned up tight and leakproof. A stock is used to turn the dies, and the same stock can be used for threading several sizes of pipe. Most pipe dies can be adjusted to cut slightly different depths of thread so that a longer or shorter thread on the end of the pipe can be obtained as desired. To cut the threads, secure the work and hold the stock as shown in figure 68; then proceed as when using any other die; keep the work well oiled. It is a good idea to test the thread with a standard pipe fitting when the operation is finished.

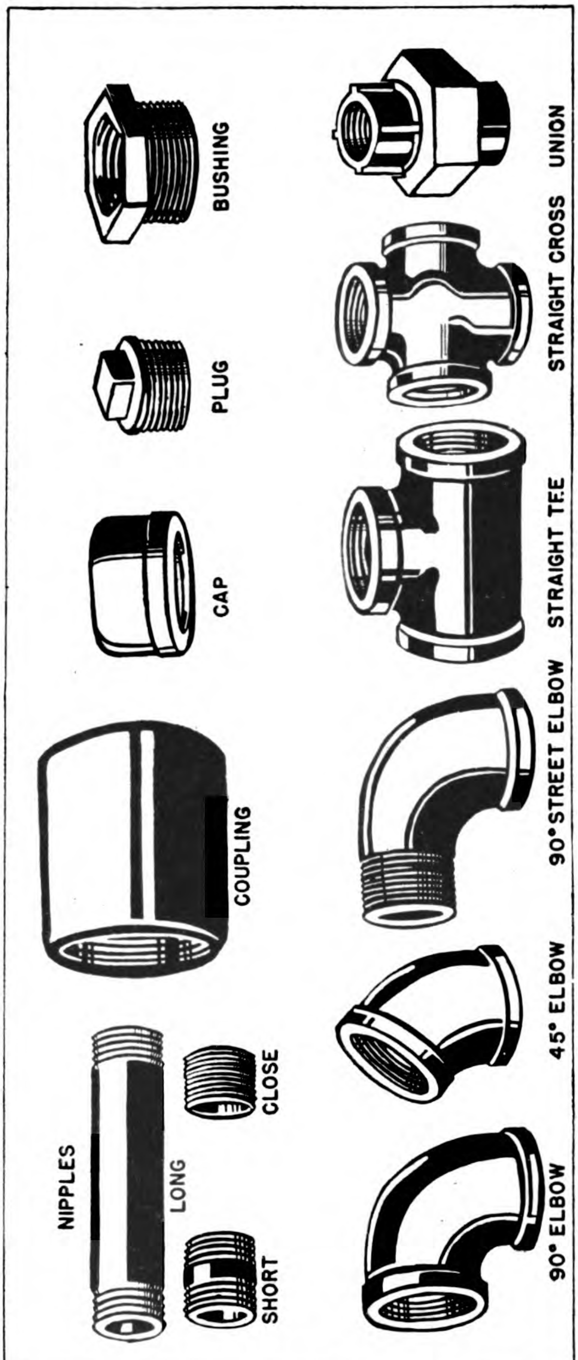

FIGURE 65.—Types of pipe fittings.

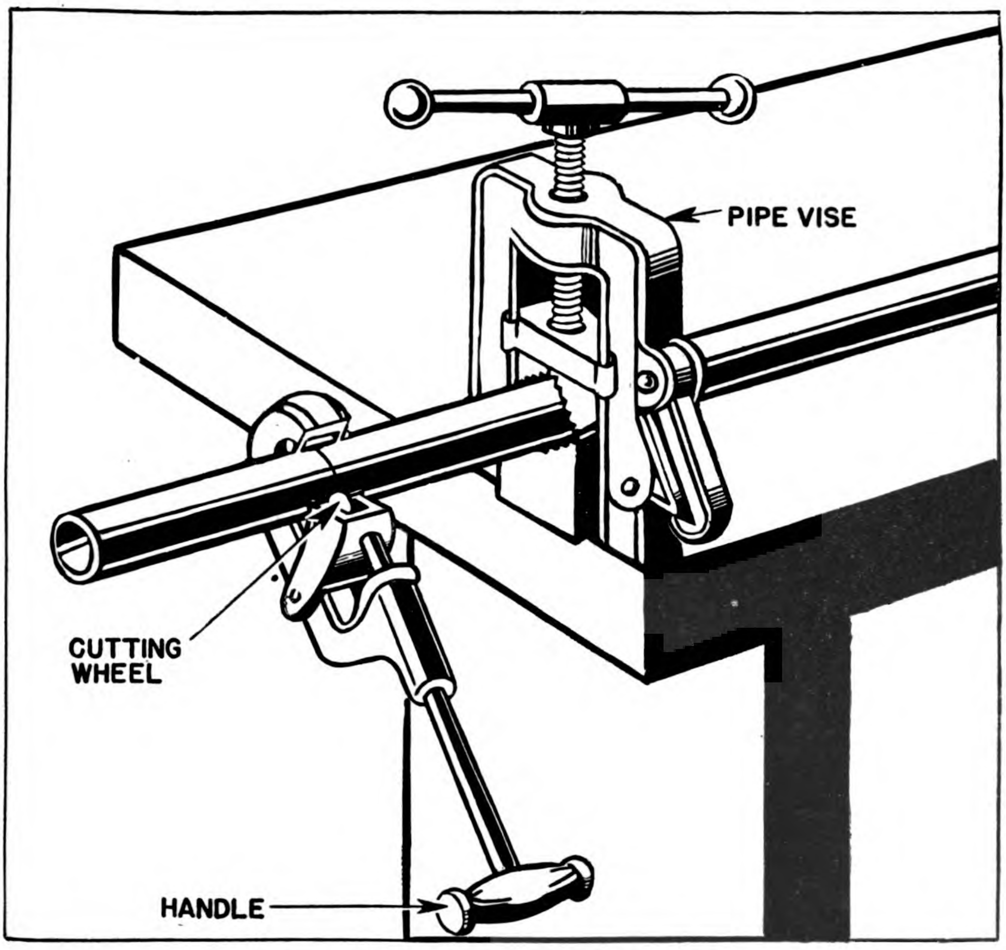

FIGURE 66.—Pipe cutter.

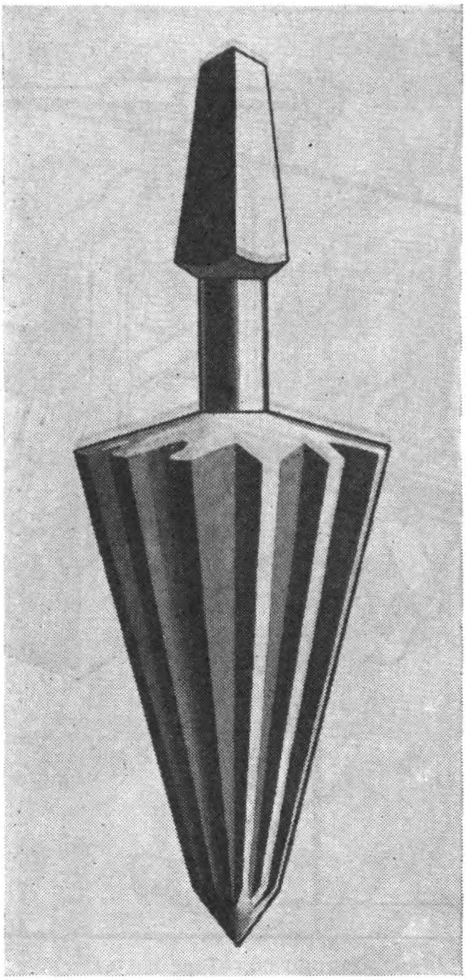

FIGURE 67.—Pipe reamer.

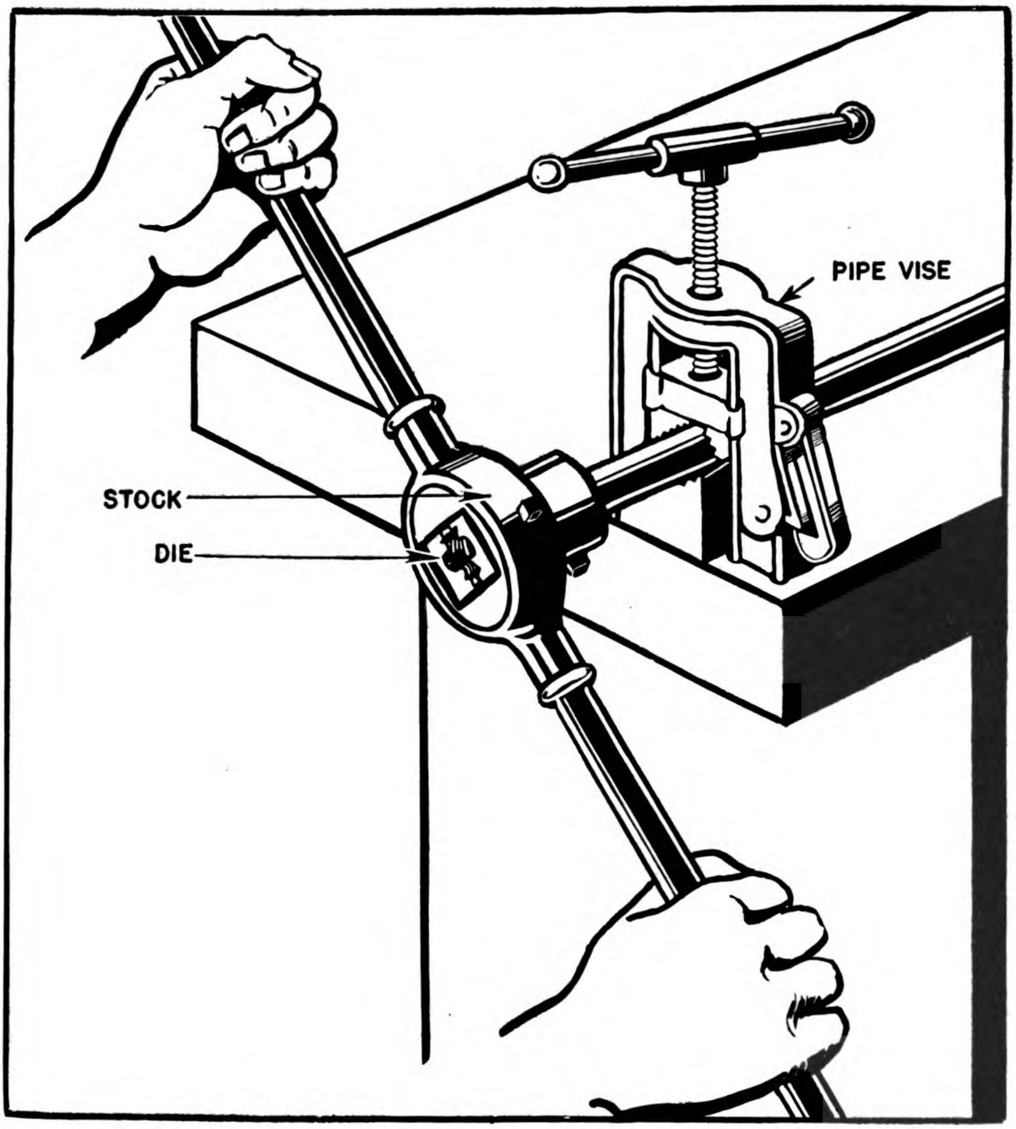

FIGURE 68.—Threading pipe.

d. Cutting and flaring tubing.—The small tubing generally used for automotive fuel lines and similar purposes can be cut with the tubing cutter, shown in figure 69. The use of the cutter is similar to the use of the pipe cutter on a much smaller scale. A reamer for removing the bur left inside the tubing is attached to the tool. It is important that the tubing be cut off at right angles to its length, especially if it is to be flared. If a flare-fitting is to be used, the flaring tool shown in figure 70 is used. The purpose of this flaring tool is to expand the end of the tubing so that it will fit into the expansion fittings frequently used on motor vehicles as tubing connections. It can also be used as a cutter. *Always be sure the fitting is placed on the tubing before using the flaring tool.* The tool

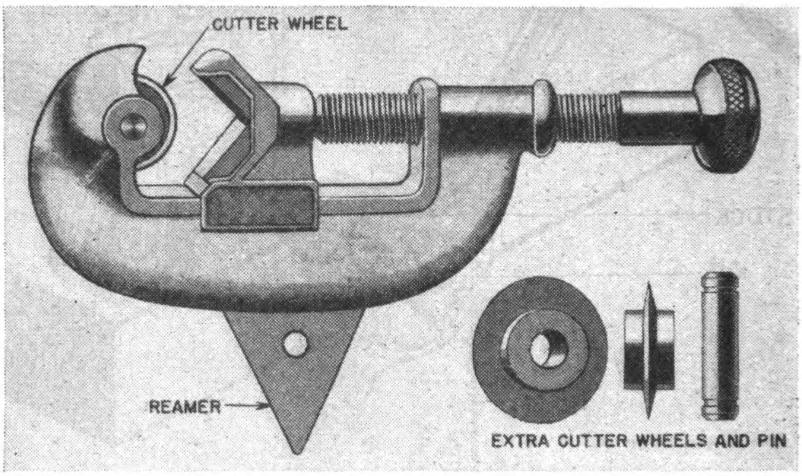

FIGURE 69.—Tubing cutter.

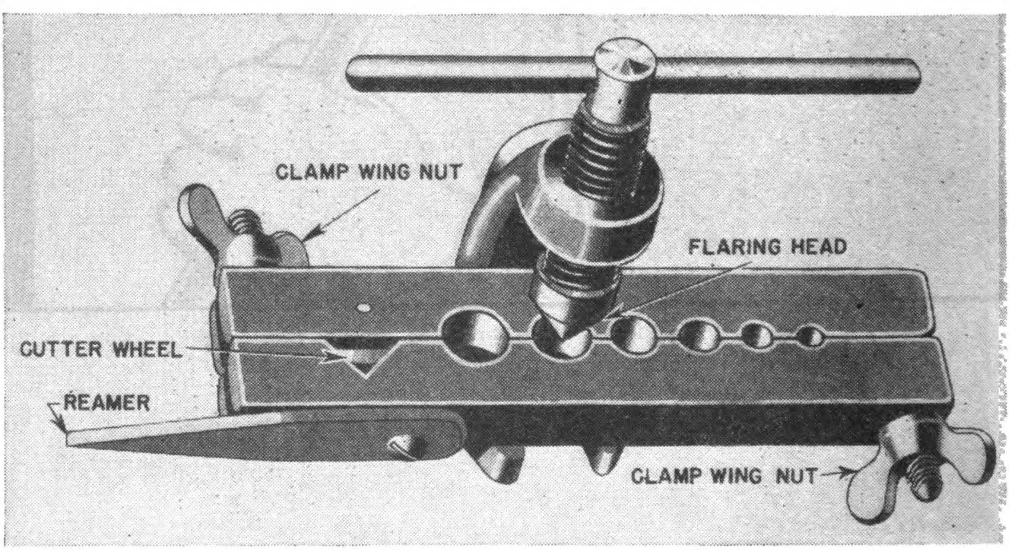

FIGURE 70.—Flaring tool.

clamps on the end of the tubing, and a tapered plug turned into the end of the tubing forms the flare.

21. Driving rivets.—Figure 55 shows the types of rivets usually found in automotive work. When the holes for the rivets have been properly located and drilled in the work, the following procedure for driving them will give good results:

a. Select the type and size of rivet to be used. The correct length will equal the thickness of the stock, plus 1½ times the diameter of the rivet. See that the rivet fits in the hole with as little clearance as possible.

b. Insert the rivet in the hole and place it *head down* on a solid surface, such as an anvil or a riveting block, as shown in figure 71.

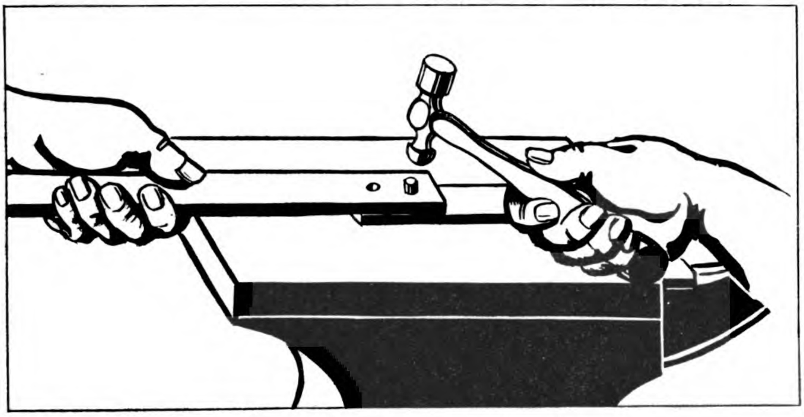

FIGURE 71.—Method of driving rivets.

c. Hold the pieces together firmly and strike the rivet a fairly heavy blow with the face of a ball-peen hammer; then strike the rivet three or four heavy blows. This will expand the body of the rivet so that it completely fills the hole.

d. Form a head on the end of the rivet by striking its outer edges glancing blows with the peen of the hammer. If the head must be formed to shape, a rivet header (fig. 72) can be used. Before peening

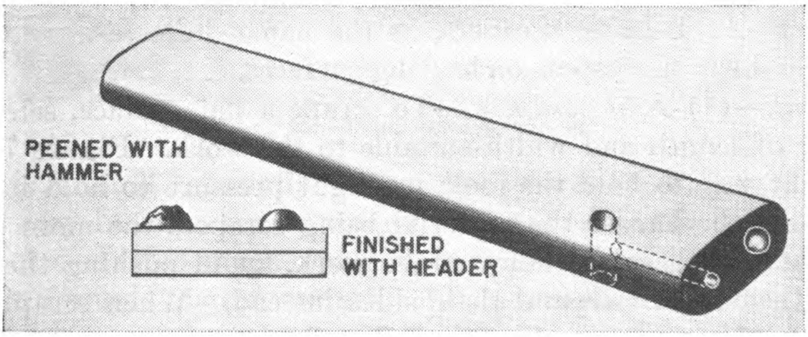

FIGURE 72.—Rivet header.

the rivet head, the hole in the bottom of the rivet header is sometimes placed over the end of the rivet, and the header struck with a hammer to force the pieces of work together.

e. When riveting leather or similar materials, use flatheaded copper rivets; place burs over the ends before heading them.

22. Scrapers.—*a. General.*—Scrapers are tools for leveling surfaces which have previously been machined and must be true. The types commonly used are flat scrapers, bearing scrapers, and three-cornered scrapers, shown in figure 73. Flat scrapers should be used for removing high spots from flat surfaces only. The three-cornered scraper is used mostly for removing burs or sharp internal edges from

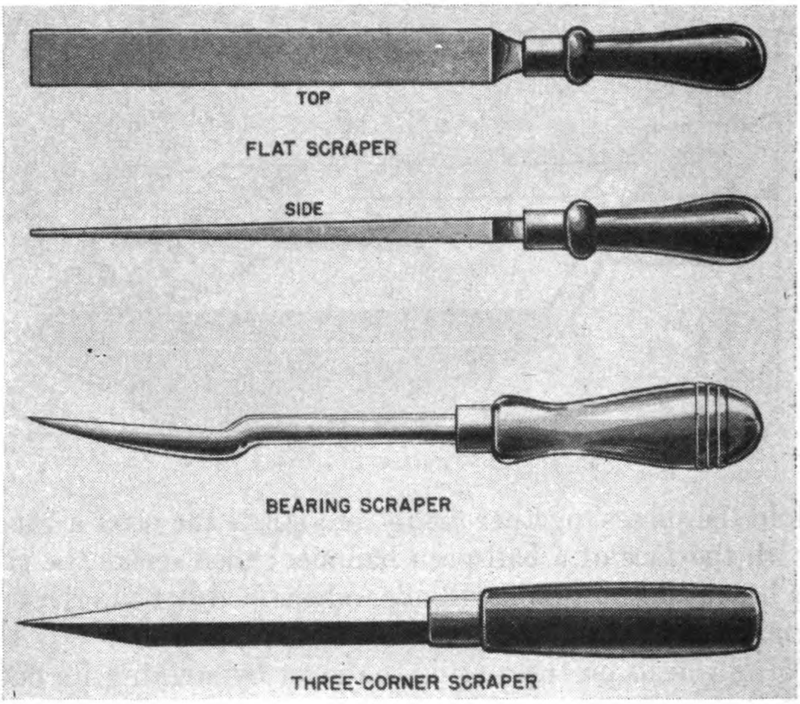

FIGURE 73.—Types of scrapers.

soft bushings and so on. (It is bad practice to perform this operation with a file.) Bearing scrapers, as the name indicates, are used for scraping down high spots on bearing surfaces.

b. Use.—(1) *Flat scrapers.*—To scrape a flat surface, select a flat scraper of length and width suitable to the work. Figure 74 shows the right way to hold the tool; use light pressure to hold it against the work; the harder the material being scraped, the more pressure required. If there are holes in the work, avoid pushing the scraper across them; work around their sides instead. When scraping near the edge of a piece, work toward the edge, or at an angle to it, *not* parallel with it.

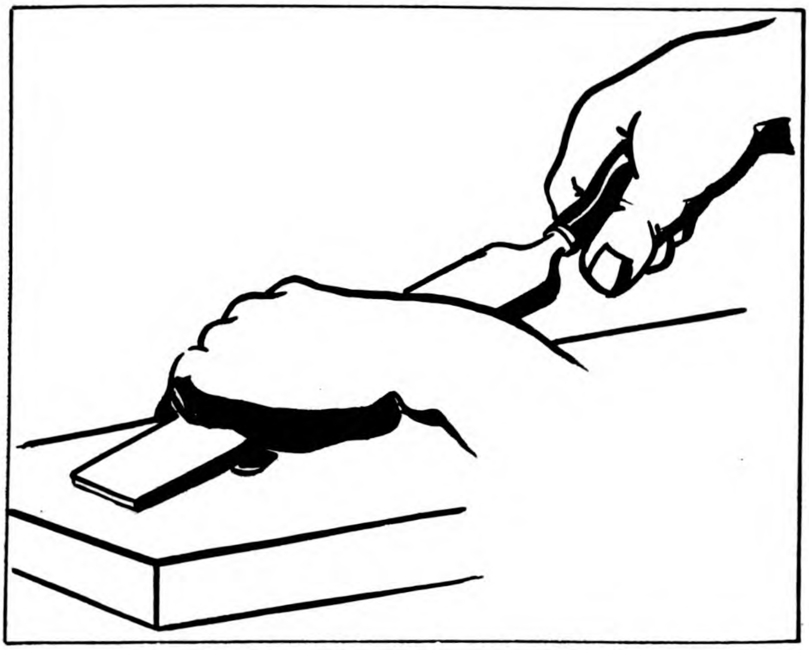

FIGURE 74.—Using flat scraper.

(2) *Bearing scrapers.*—It often becomes necessary, especially under emergency conditions, for the mechanic to fit or scrape in a bearing. Figure 75 illustrates the correct way to hold the bearing scraper; use a light, twisting motion of the hand that holds the handle, while the other hand steadies the tool. The cutting edge of the bearing

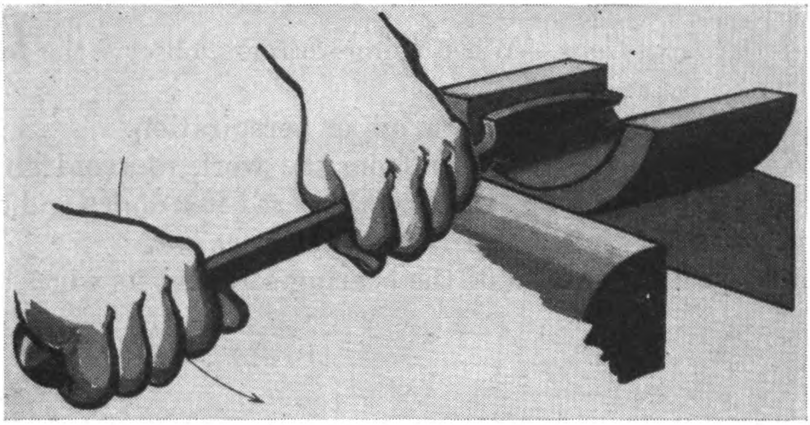

FIGURE 75.—Using bearing scraper.

scraper is ground especially for working on babbitt metal; its use requires very little pressure; remove only a small amount of metal at each stroke. If too much pressure is applied, the tool will chatter and leave a rough, uneven surface. When scraping a bearing, always work crosswise, not lengthwise, of the work.

(3) *Three-cornered scrapers.*—When using a three-cornered scraper, work with one hand only, using the same twisting motion as though handling a bearing scraper. As a rule, the three-cornered scraper is used on material requiring fairly firm pressure; but only a small amount of metal should be removed at each stroke.

(4) *Carbon scrapers.*—The carbon scraper (fig. 76) is a tool commonly used by motor vehicle mechanics for cleaning carbon deposits from cylinder heads, pistons, and chambers of gasoline engines. This scraper has a dull edge to lessen the danger of scoring the piston or cylinder wall.

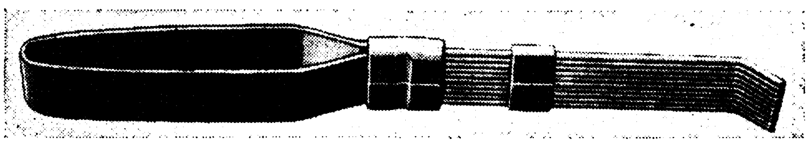

FIGURE 76.—Carbon scraper.

c. Care of scrapers.—Keep scrapers (except the carbon scraper) sharp at all times, or they will not leave a smooth surface and will require more pressure than is necessary. The usual method of sharpening is first to grind the tool on a small emery wheel, then to finish the operation on an oilstone. To use the oilstone, proceed as shown in figure 77, first stoning the flat sides of the scraper and finally squaring up the end. In scraping any surface, apply pressure to the scraper on the cutting stroke only, otherwise the tool will soon become dull.

d. Safety precautions.—When using scrapers, observe the following precautions:

(1) Keep hands free of grease, oil, or perspiration.

(2) Keep hands high enough from the work to avoid striking a corner of it while scraping; these corners are often sharp and can give the hand a disagreeable and perhaps dangerous cut.

(3) Be especially careful of the bearing scraper; its edges are very sharp.

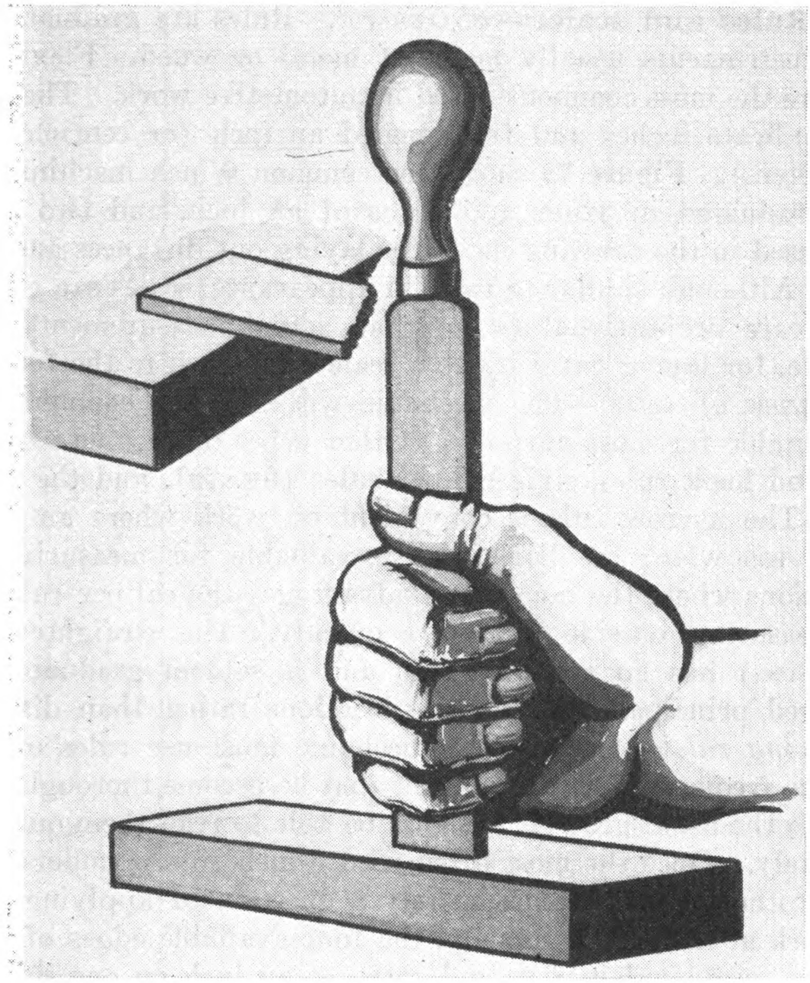

FIGURE 77.—Using oilstone to sharpen flat scraper.

SECTION III

USE AND CARE OF MEASURING TOOLS

23. Rules and scales.—*a. General.*—Rules are graduated measuring instruments usually made of metal or wood. Flexible steel rules are the most commonly used in automotive work. The graduations indicate inches and fractions of an inch (or centimeters and millimeters). Figure 78 shows the common 6-inch machinist's steel rule, graduated in 32nds and 64ths of an inch, and two types of scales used in the drawing room for laying out distances and dimensions. Although similar to rules in appearance, scales are graduated to indicate proportional rather than actual measurements; as, for example, for laying out work to a scale of ¼ inch to the foot.

b. Types of rules.—The mechanic will find the common flexible rule suitable for most purposes. Other types often used are narrow rules and hook rules, slide caliper rules (fig. 79), and the straightedge. The narrow rule is convenient on work where an ordinary rule is too wide; the hook rule is valuable for measuring inside dimensions where the hook is an advantage; the caliper rule is used for measuring outside diameters quickly. The straightedge (not illustrated) has an accurate edge and is seldom graduated, being employed principally for finding locations rather than distances.

c. Using rules.—Because the mechanic must use rules of various kinds so frequently, it is important that he become thoroughly familiar with the usual graduations, and be able to read them quickly and accurately. Once the most often used 6-inch rule is understood, the use of other types becomes merely a question of applying them to the work at hand. Ordinarily, the four available edges of a 6-inch rule are graduated in 8ths and 16ths of an inch on one side and in 32nds and 64ths on the other. Figure 80 shows the two sides of such a rule. The following procedure is recommended for learning to read it: first, learn the 8ths and 16ths, then the 32nds and 64ths, and become thoroughly familiar with the readings shown in figure 81. Practice in reading measurements similar to the examples in figure 82 will soon enable the student to obtain accurate measurements very quickly with any type of rule. Figure 83 shows the usual methods of measuring work of several common shapes.

24. Scribers.—The scriber (fig. 84) is used for marking lines on metal, especially in connection with measuring with a rule. Centers can be located with it by using it to draw two intersecting lines and marking the intersection with a prick punch. The bent end is convenient for marking the inside of cylindrical objects or partially closed recesses. Keep the scriber sharp and use it like a pencil with only enough pressure to make a clear mark.

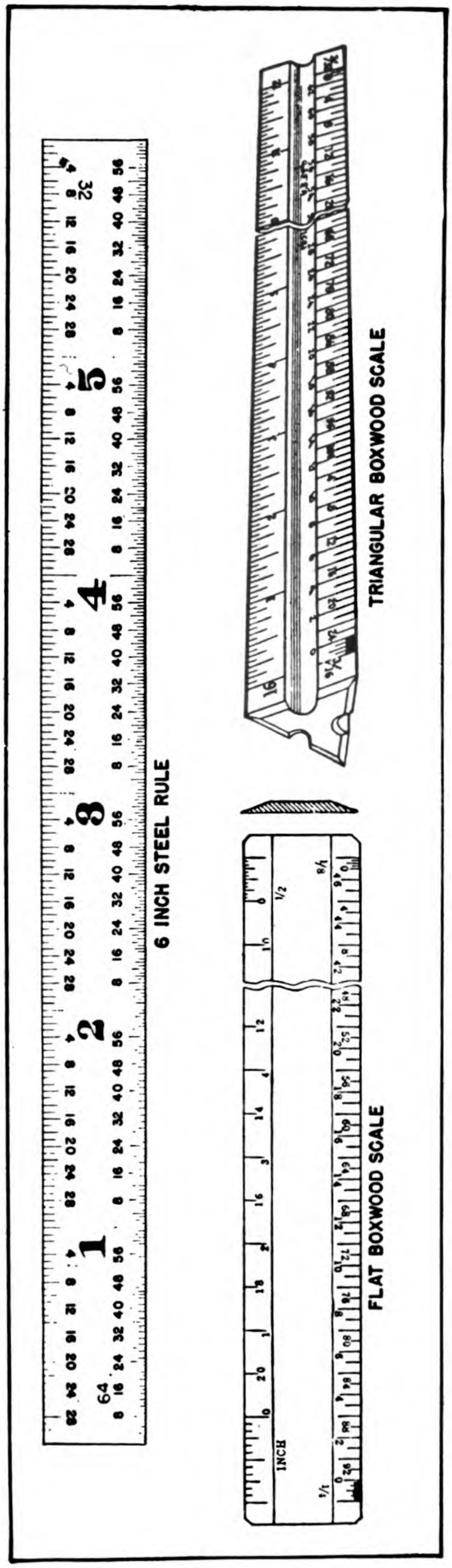

FIGURE 78.—Six-inch steel rule and scales.

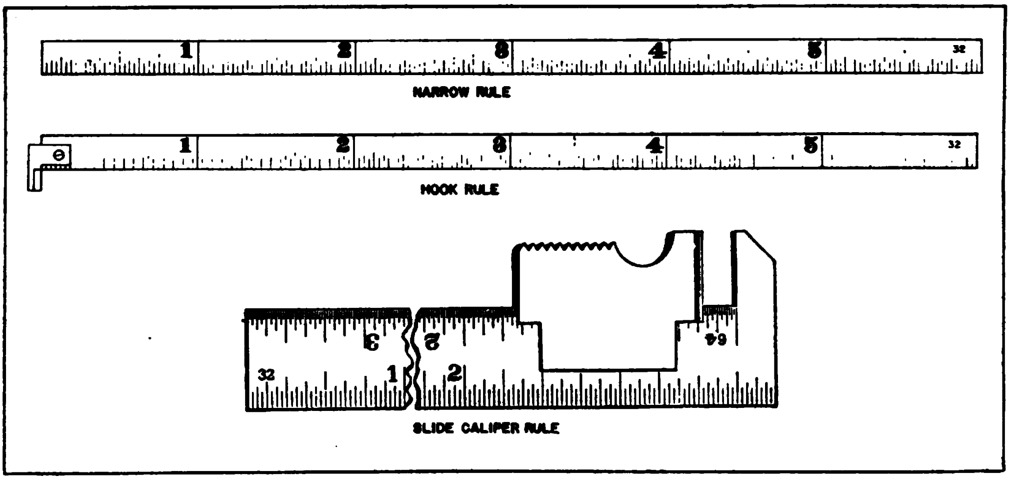

FIGURE 79.—Narrow, hook, and caliper rules.

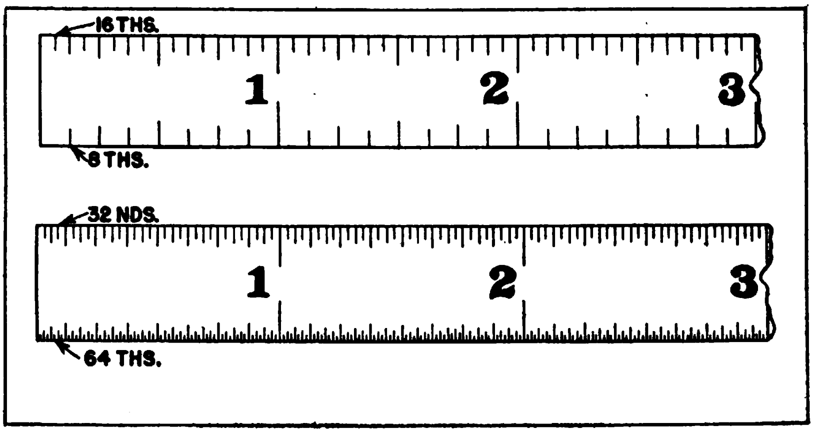

FIGURE 80.—Two sides of 6-inch rule.

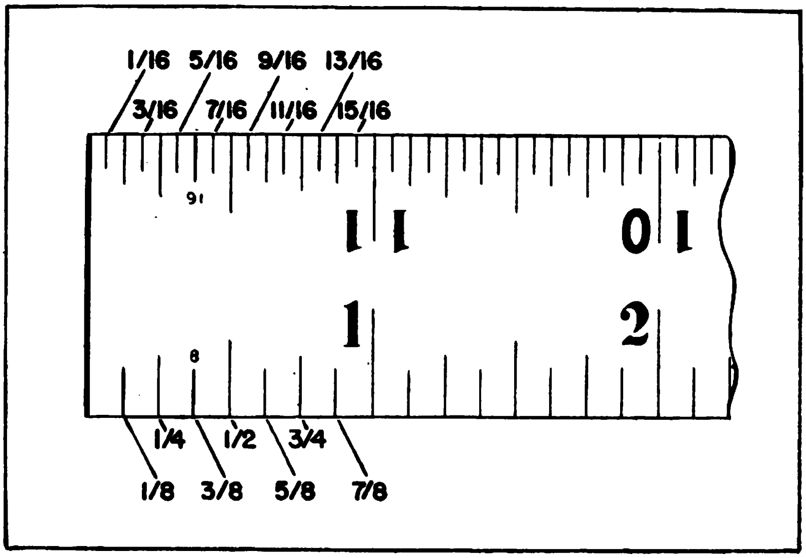

FIGURE 81.—Readings on 6-inch rule.

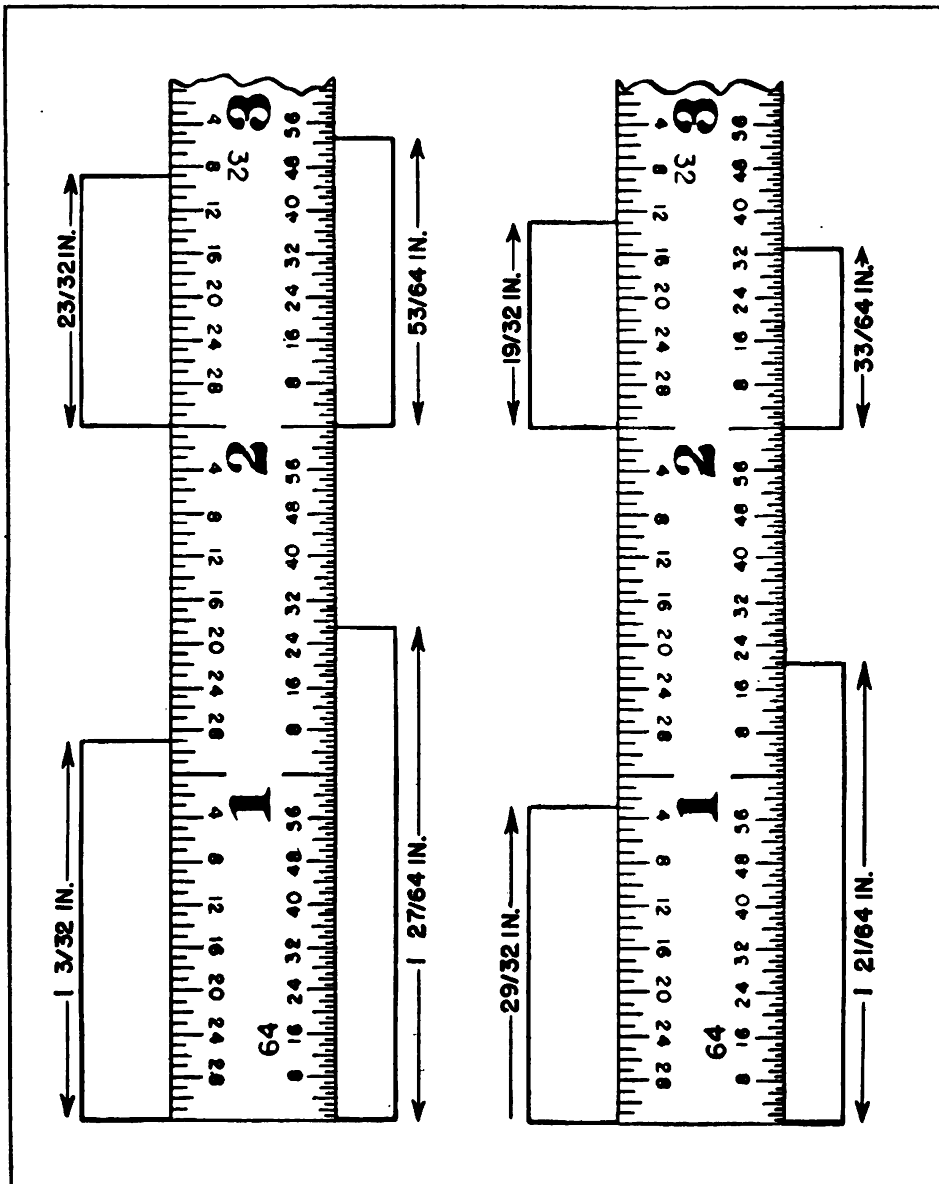

FIGURE 82.—Practice measurements for 6-inch rule.

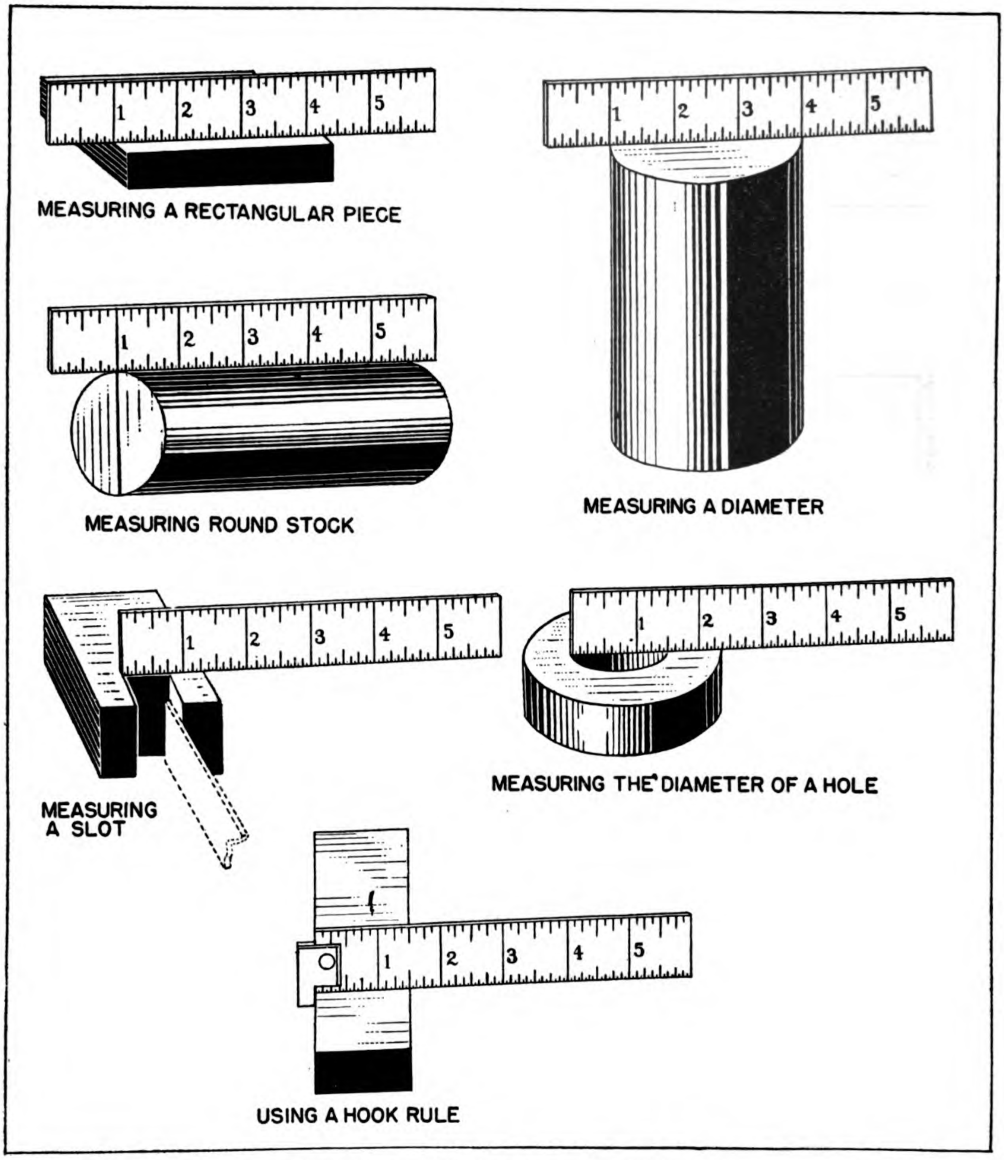

FIGURE 83.—Applications of 6-inch rule.

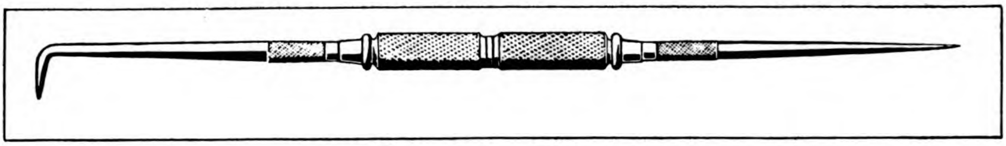

FIGURE 84.—Scriber.

25. Squares.—*a. General.*—Squares are used for measuring angles or locating and laying out centers on round work. Figure 85 shows the commonly used types. The solid square is convenient and accurate for measuring right angles only; the carpenter's steel square

is used by carpenters for laying out woodwork and, quite often, by mechanics for lay-out jobs on large metal surfaces. The combination set is used most often by automotive mechanics and machinists, and familiarity with its numerous applications should be acquired.

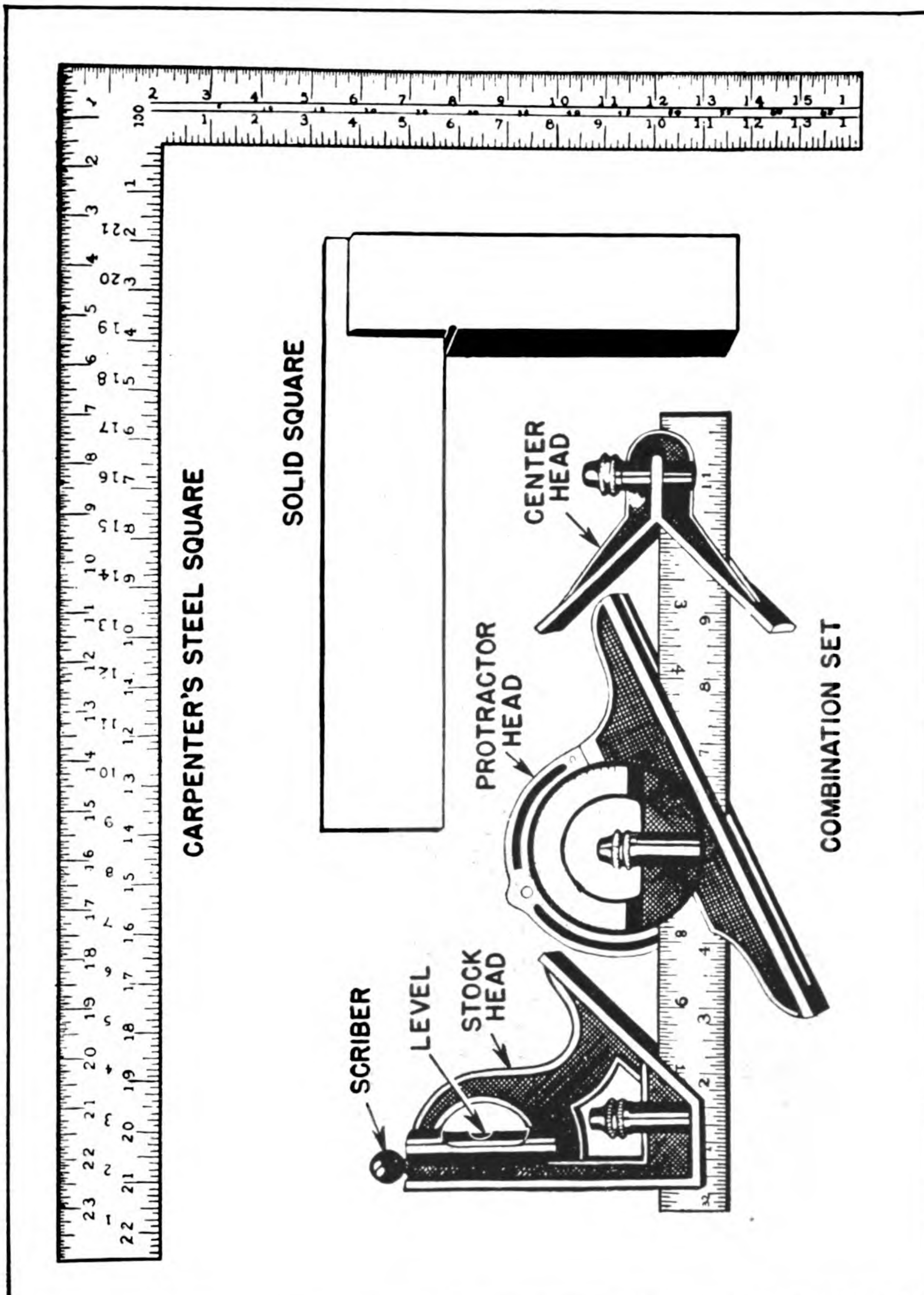

FIGURE 85.—Types of squares.

b. Use of combination set.—The illustration of the combination set in figure 85 shows it equipped with a protractor head and a center head, as well as the stock 90° and 45° head. These accessories are readily removable, so that the one needed can be quickly attached to the blade. A number of common applications of the stock and center heads are shown in figure 86. The protractor head is used for measuring angles other than 45°or 90°, but is less com-

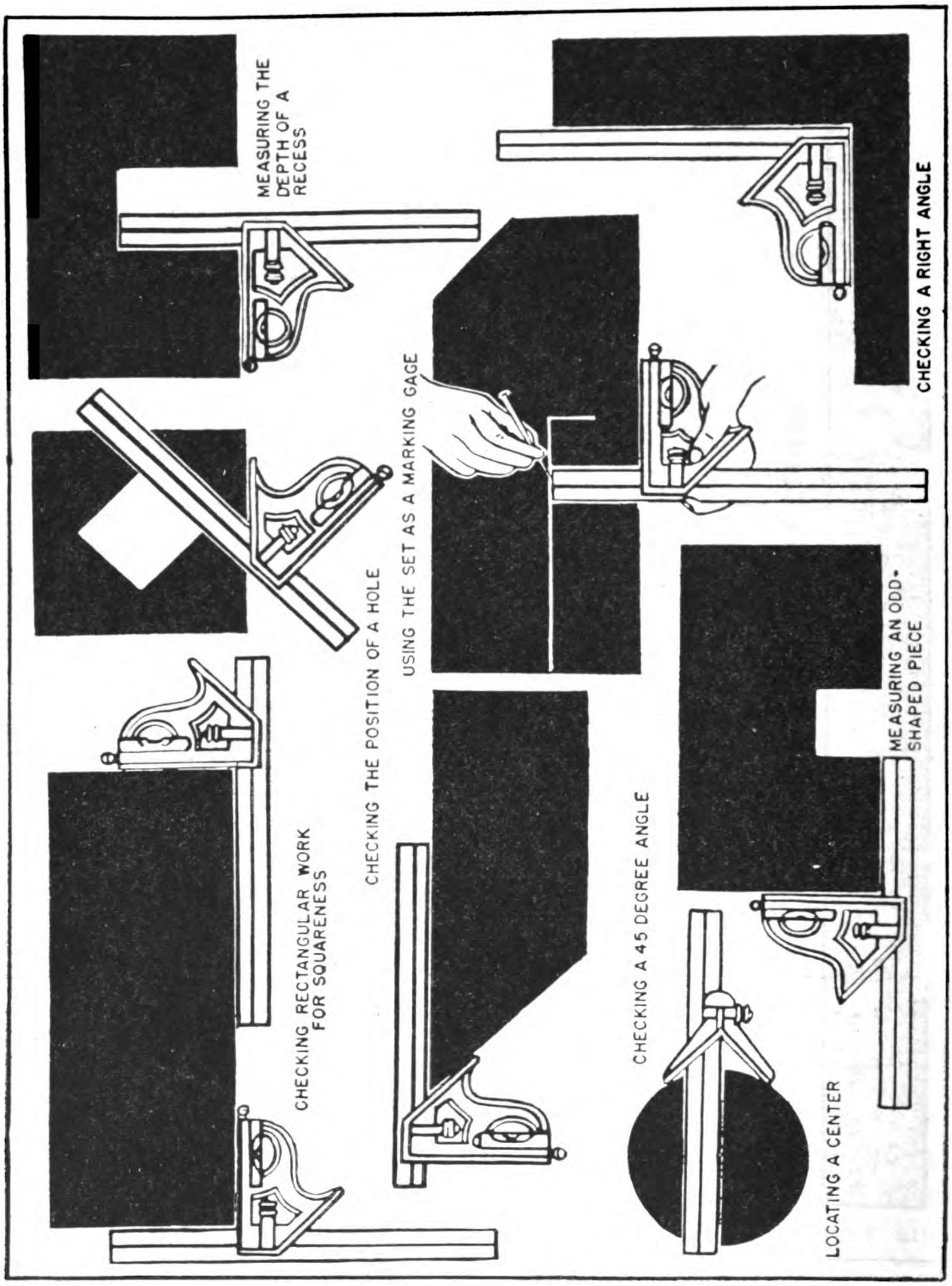

FIGURE 86.—Applications of combination set.

monly required for most automotive work than the stock and center heads. Be sure that the blade and accessories of the combination set are kept clean, or inaccurate measurements may result; apply a small amount of oil to the blade occasionally with a rag to keep it from rusting.

26. Calipers.—*a. General.*—Calipers are used for measuring diameters and distances or comparing distances and sizes. The three common types are inside calipers, outside calipers, and hermaphrodite calipers, as shown in figure 87.

b. Outside calipers.—Outside calipers are used for measuring outside dimension, as, for example, the diameter of a piece of round stock (fig. 88). The calipers should first be set approximately to the diameter of the work; then, while held at right angles to the center line of the stock, adjusted until their points bear *lightly* on the surface of the work. Move the points back and forth slowly while adjusting them in order to get the "feel." When the adjustment has been made, the diameter can be read from a rule as shown in figure 88.

c. Inside calipers.—Inside calipers have curved legs for measuring inside diameters, such as the diameters of holes, the distance between two surfaces, the width of slots, and other similar jobs. To measure the inside diameter of a hole, for example, with inside calipers, first set them approximately to the size of the hole; then, holding one leg against the wall of the hole, adjust the other leg until it just touches the point *exactly opposite*, as shown in figure 89. The dimension can then be determined with a rule or a micrometer as shown. With practice one can caliper a hole within one half-thousandth of an inch.

d. Hermaphrodite calipers.—Hermaphrodite calipers are generally used to scribe arcs, or as a marking gage in lay-out work, as shown in figure 90. To adjust them to a rule, set the scriber leg slightly shorter than the curved leg; then with the curved leg against the *end* of the rule, adjust the scriber leg to the desired graduation on the rule. Hermaphrodite calipers should not be used for precision measurements.

e. Dividers.—Dividers are tools for measuring distances between points, for transferring distances directly from a rule, or for scribing circles or parts of circles. Figure 91 shows a pair of dividers of a type commonly used. They are convenient for dividing spaces into equal parts or determining the dimensions of irregularly shaped work. Keep the points of dividers sharp, and use only enough pressure on them to make a clear scribed mark on the work.

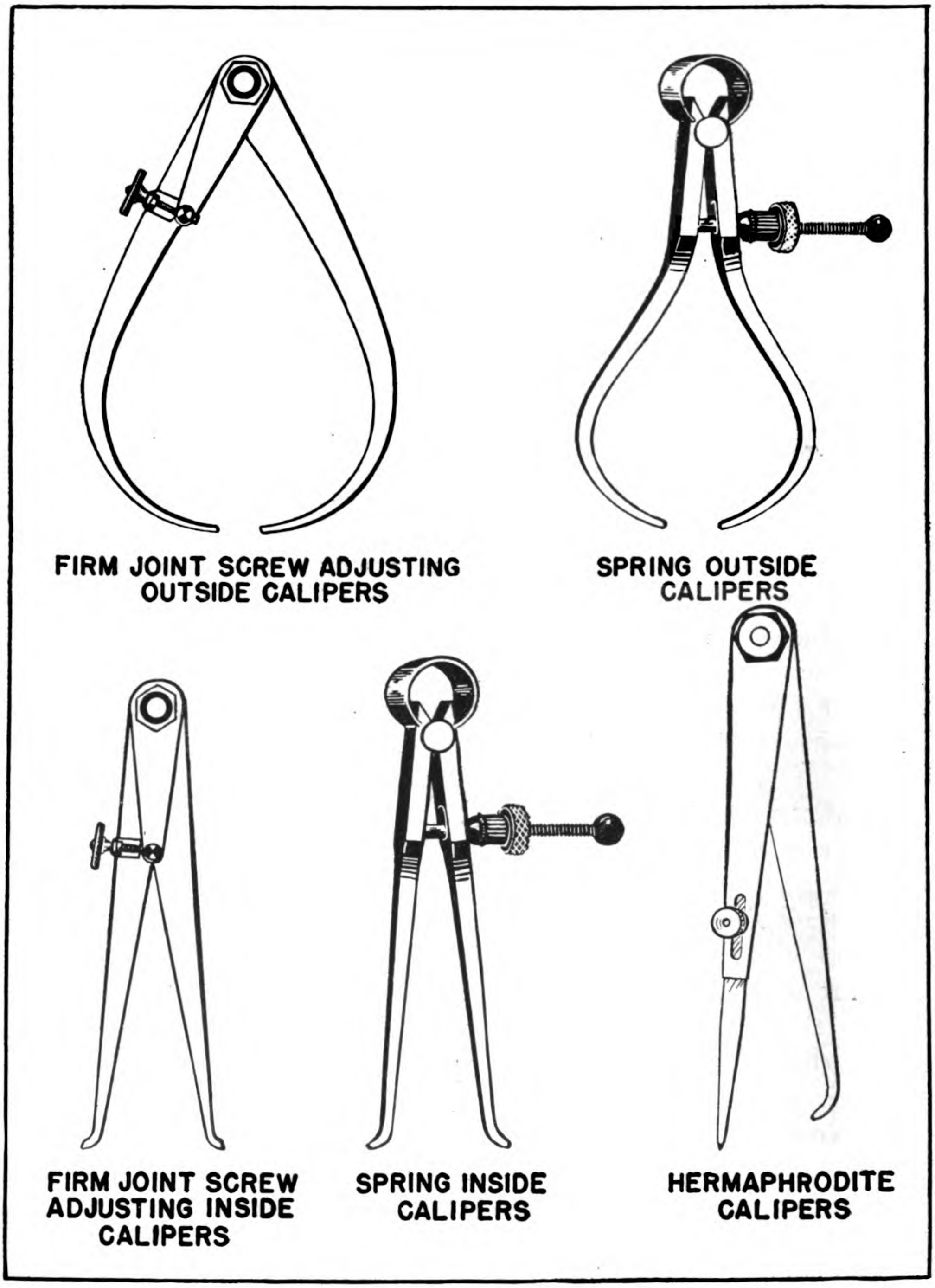

FIGURE 87.—Calipers.

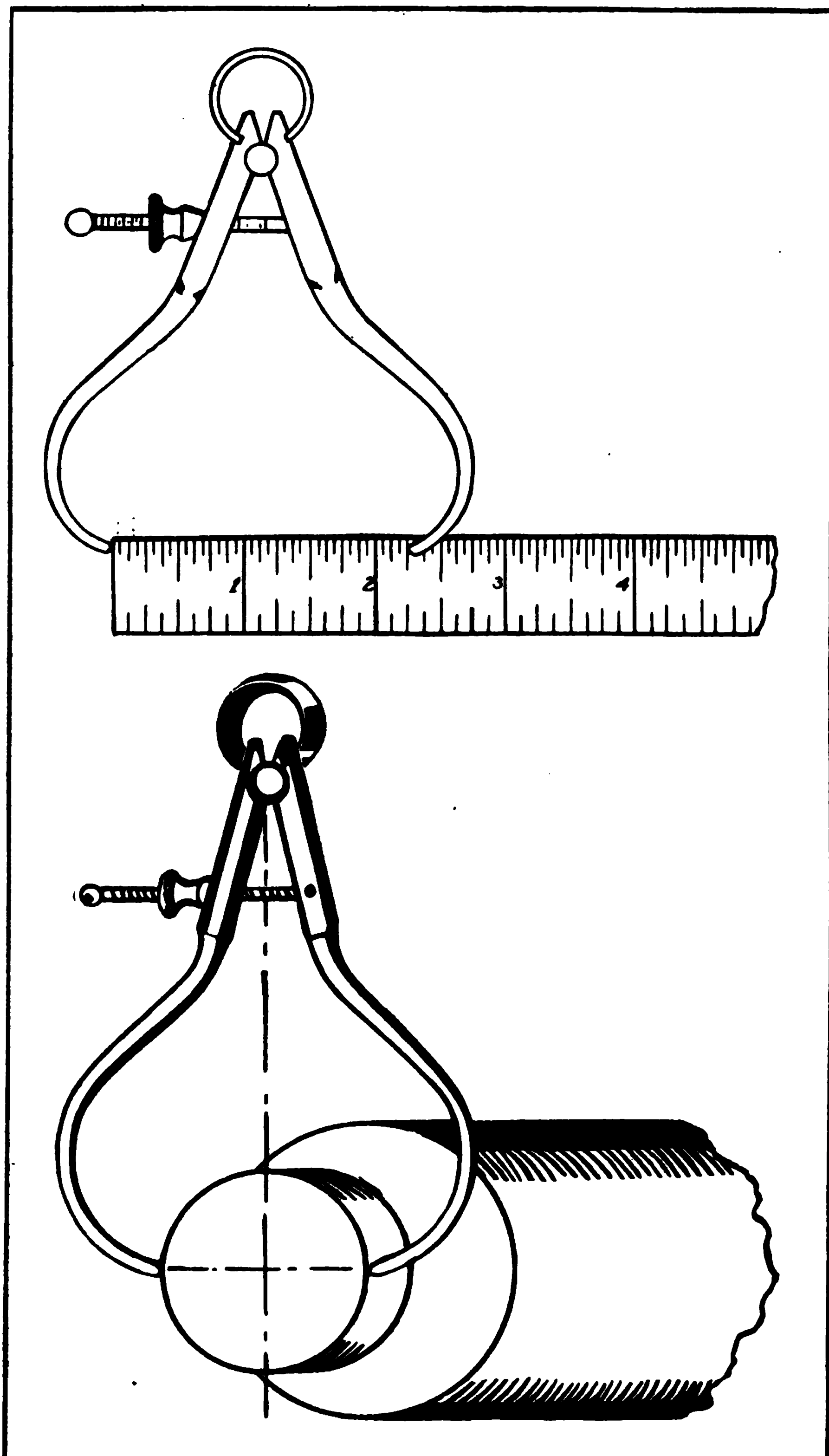

FIGURE 88.—Measuring round stock with outside calipers.

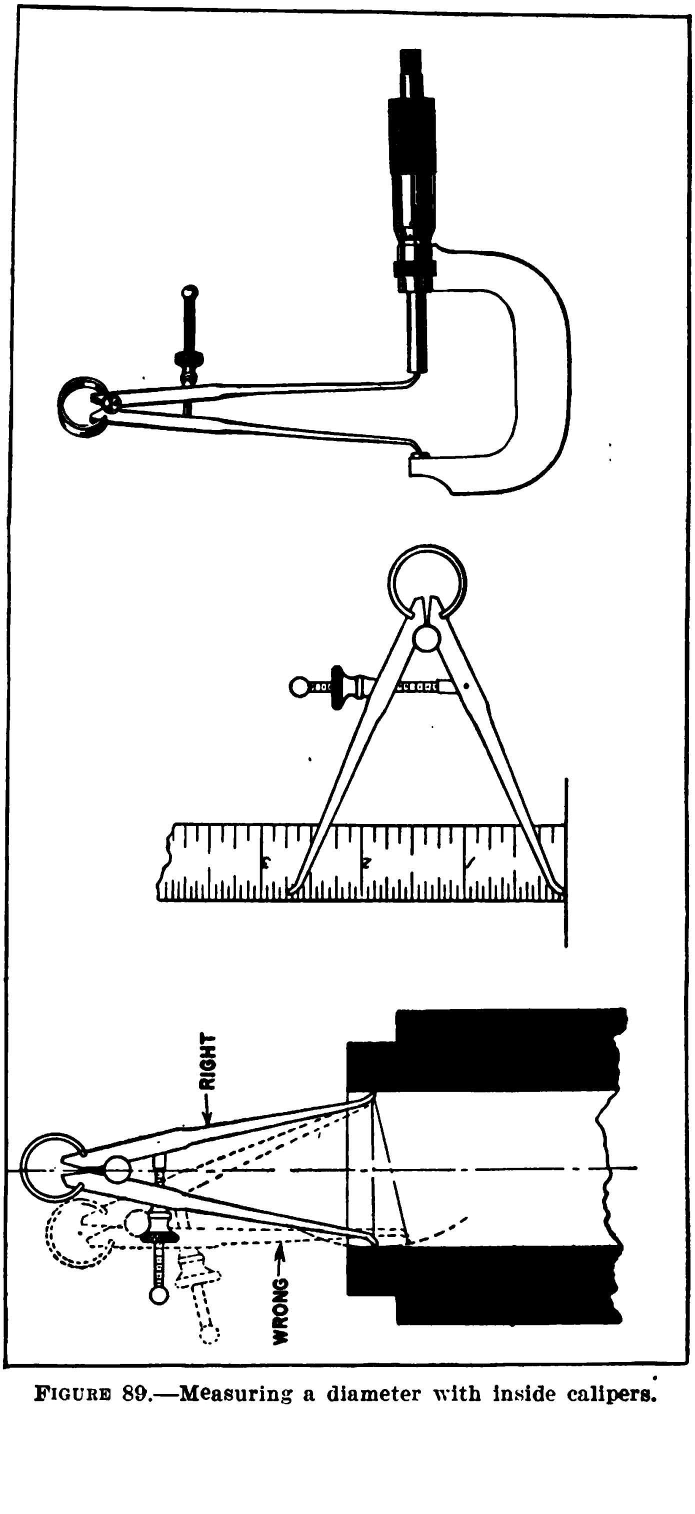

FIGURE 89.—Measuring a diameter with inside calipers.

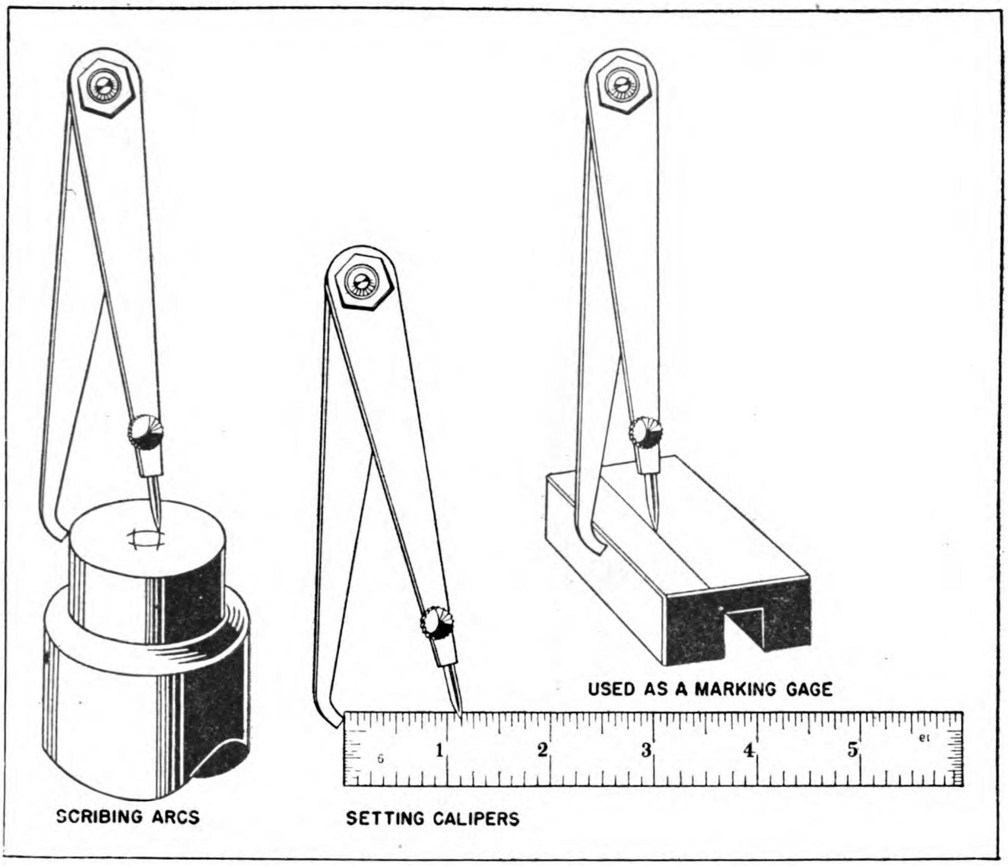

FIGURE 90.—Three uses of hermaphrodite calipers.

27. Fixed gages.—*a. General.*—Gages are tools for measuring or transferring distances or dimensions, usually within one one-thousandth of an inch or less. They are made both adjustable and nonadjustable; this section deals only with gages which are nonadjustable or fixed. A fixed gage is made with extreme accuracy to some fixed standard of measurement or shape, so that when it is applied to a piece of work, the standard is transferred to the work. For example, if a mechanic wants to fix two surfaces, say six thousandths of an inch apart, he will adjust them until a piece of metal *known* to be six thousandths of an inch thick will just fit between them. Such a piece of metal would be a fixed gage. Fixed gages are generally made, either individually or in sets of two or more, for some specific operation, or for transferring some particular measurement, such as gaging thickness, threads, diameters, depths, and so on.

b. Types of fixed gages.—A fixed gage can be obtained for practically any close measurement in automotive work; thickness gages

and screw thread gages are examples of fixed or nonadjustable gages often used in motor vehicle maintenance and repair. Plug gages and ring gages (fig. 92) are used in production work to check inside and outside dimensions for size and to see that finished parts are within the manufacturing tolerance. (Tolerance is the allowable variation in a dimension that is permissible without rejection of the finished part when inspected.) Fixed gages are usually made in pairs, either

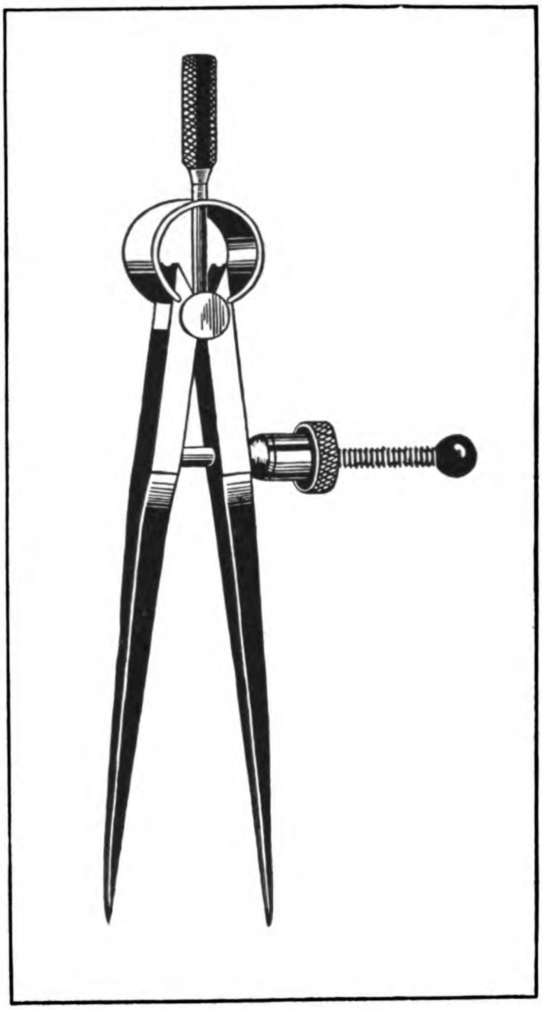

FIGURE 91.—Dividers.

in one piece or two units. For instance, a plug gage generally has a "go" end and a "no go" end. If the "go" end of such a gage will enter a finished hole and the "no go" end will not, the hole is within the tolerance for which the gage was designed. If the "go" end of the gage will not enter the hole, the hole is too small. If the "no go" end of the gage, being slightly larger than the "go" end, does

enter the hole, the hole is too large. Plug thread gages and ring thread gages are similar, except that they are threaded to check the accuracy of inside or outside threads. Outside caliper or snap gages (fig. 93), also used almost exclusively in production work, are for checking the dimensions of round or flat-surfaced pieces; inside caliper gages (not illustrated)are used much as a plug gage for testing

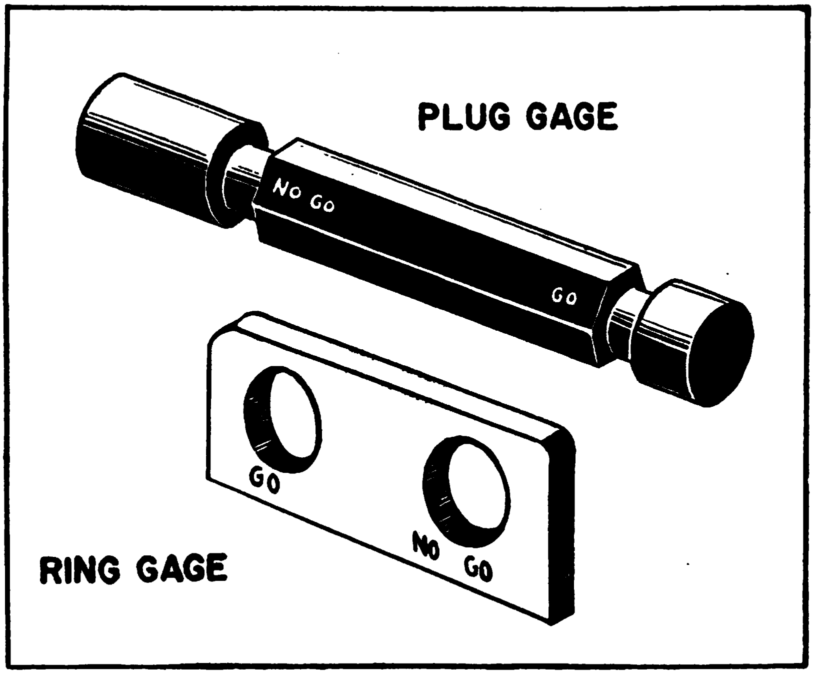

FIGURE 92.—Plug gage and ring gage.

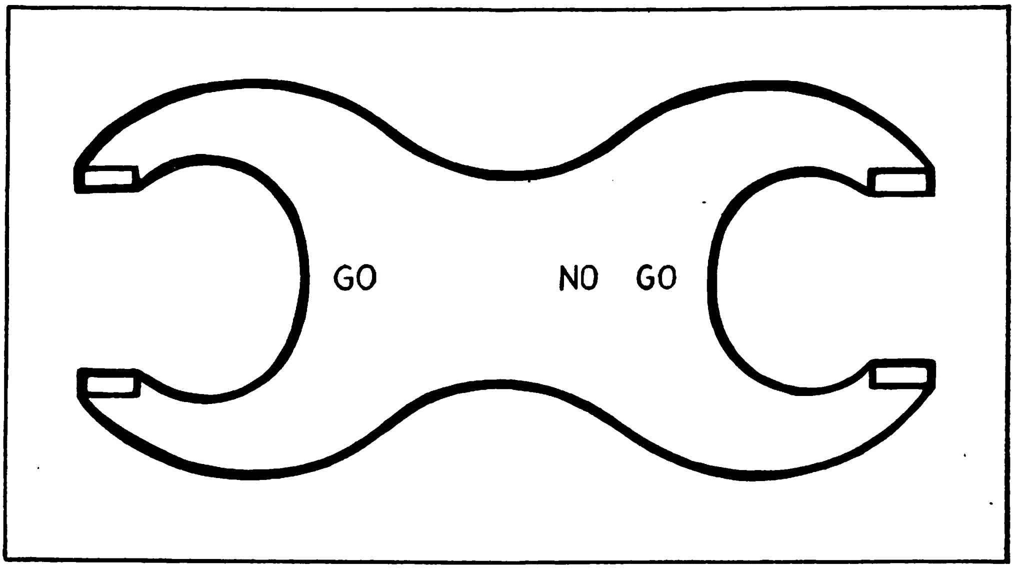

FIGURE 93.—Outside caliper (snap) gage.

inside dimensions. The thickness gage (fig. 94) is very commonly used in automotive work for measuring the distance between two surfaces, as, for example, the clearance of valve tappets. The radius gage (fig. 95) measures small outside or inside radii, as illustrated. The screw thread gage (fig. 58) measures the pitch, or number of threads per inch, of threaded parts.

c. Using fixed gages.—All fixed gages are made for measuring some *specific* dimension; for example, a ¾-inch caliper gage or a 0.002-

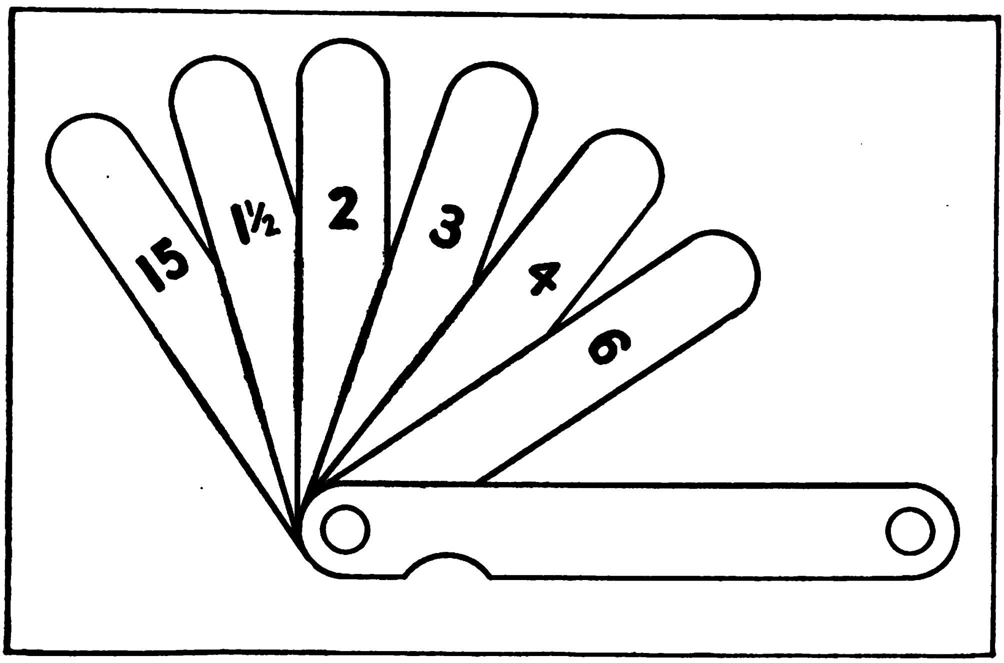

FIGURE 94.—Thickness gage.

inch thickness gage. Handle them carefully; any strains imposed on them by forcing them over or into a piece of work or by dropping them can distort them enough to spoil their accuracy. See that their measuring surfaces, as well as the surfaces of the work, are clean and smooth; do not under any circumstances *force* a gage on any job. They are instruments of extreme precision; check them periodically with some standard to make sure they have not changed in size because of wear or damage.

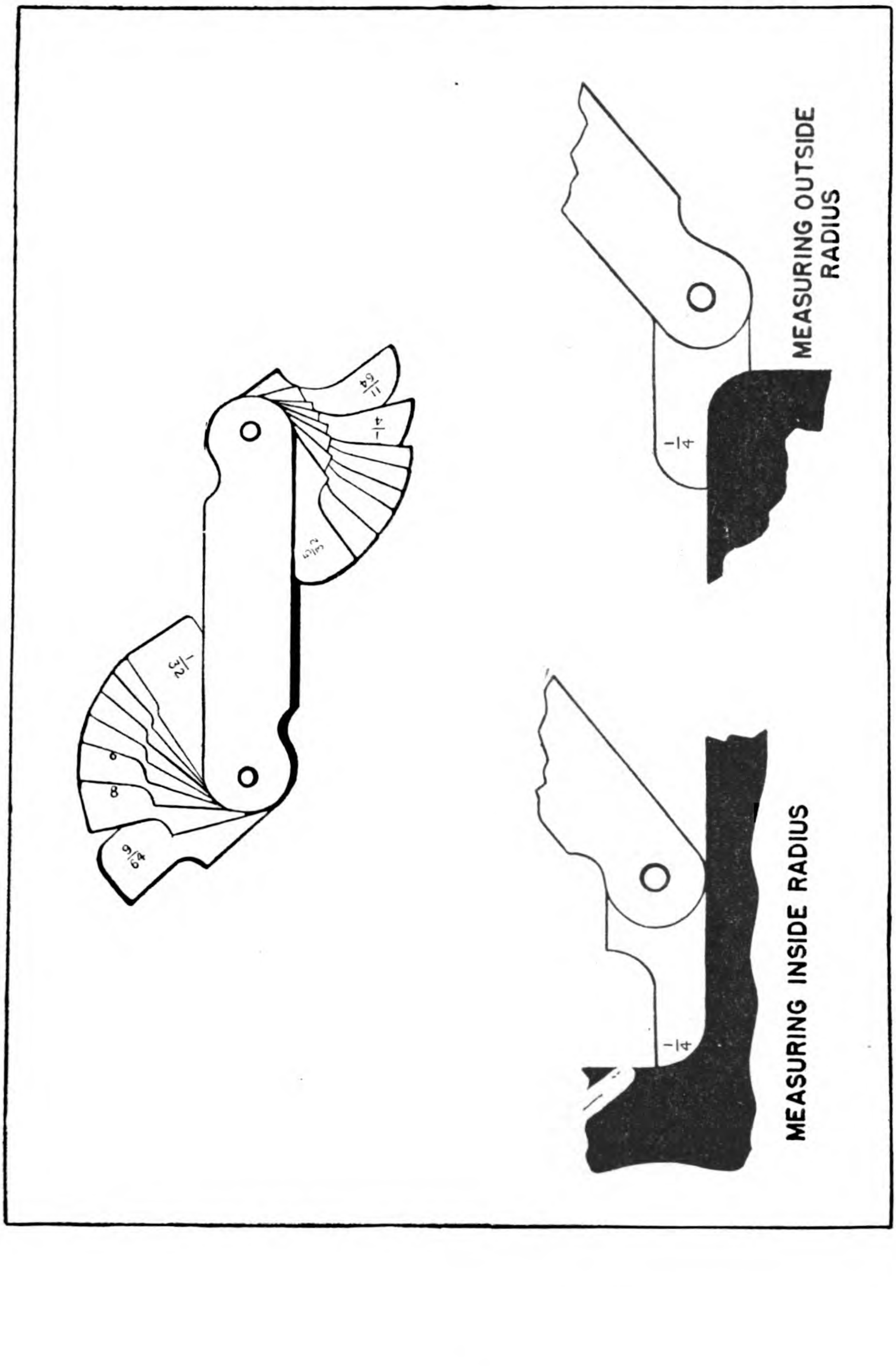

FIGURE 95.—Radius gage and use.

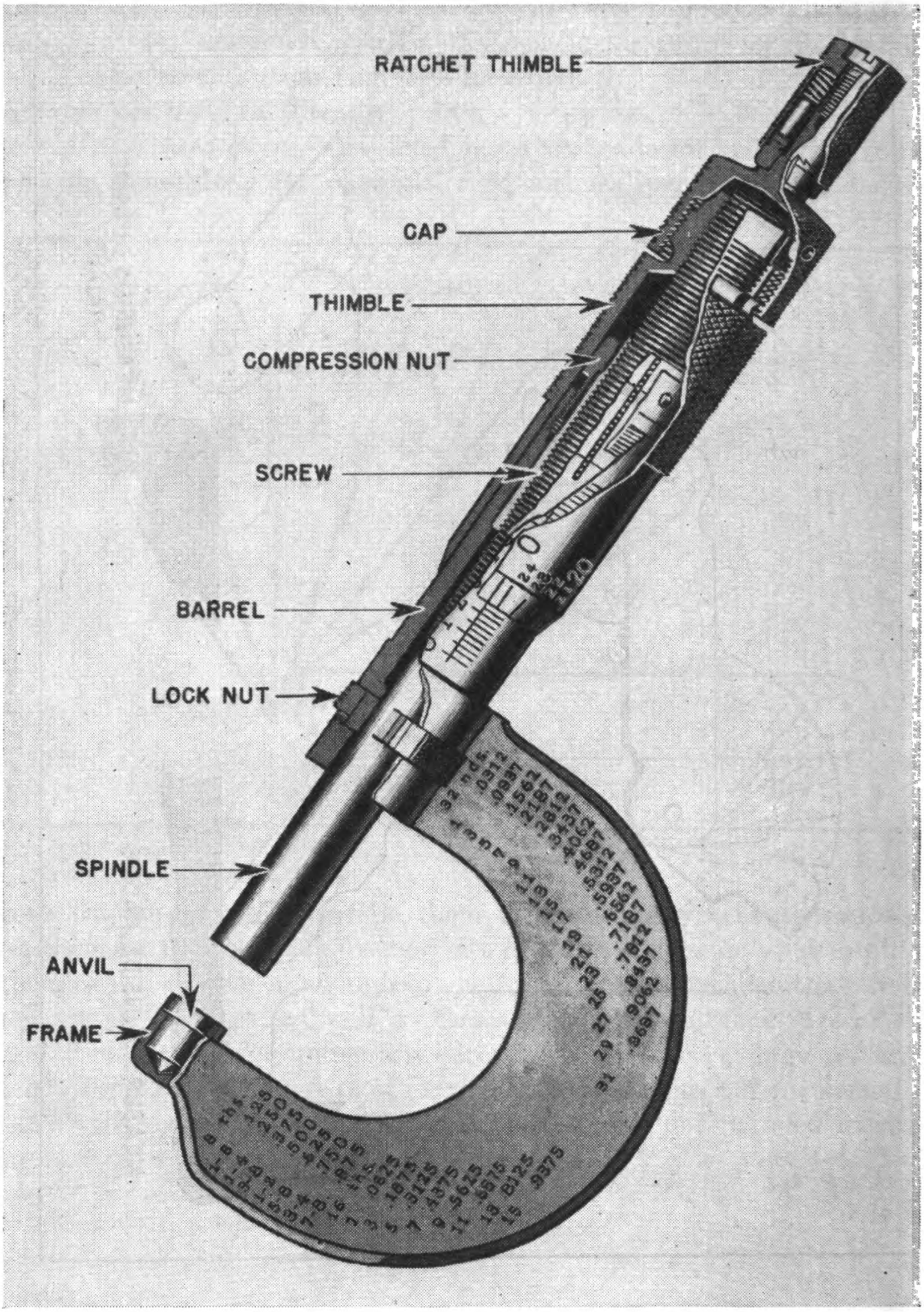

FIGURE 96.—Sectional view of outside micrometer.

28. Micrometer calipers.—*a. General.*—The micrometer is the most commonly used adjustable gage, and it is important that the mechanic understand thoroughly its mechanical principles, construction, use, and care. Figure 96 shows a 1-inch outside micrometer caliper with the various parts clearly indicated. Before making any attempt to use the tool, the mechanic should become familiar with its nomenclature, especially the frame, anvil, spindle, barrel (or sleeve), screw, and thimble. Micrometers are generally intended to measure distances to one ten-thousandth of an inch; the measurement is usually expressed or written as a decimal, so the mechanic should also know the method of writing and reading decimals.

b. Decimals.—The decimal system is a method of expressing fractions and mixed numbers. For example, 2.000 inches written decimally indicates exactly 2 inches. All figures to the *left* of the decimal point are whole numbers; all figures to the *right* of it indicate parts of whole numbers. Starting from the decimal point and moving to the right, the first digit indicates tenths; the second, hundredths; the third, thousandths; the fourth, ten-thousandths; and so on. Thus, 2.3 is read two and three-tenths; 1.85 is read one and eighty-five hundredths; 4.071 is read four and seventy-one thousandths; 0.2318 is read twenty-three hundred and eighteen ten-thousandths. (When there is no number to the left of the decimal point, the quantity indicated is less than 1.)

c. Types of micrometers.—Three types of micrometers are commonly used in automotive work: the outside micrometer (including the screw thread micrometer), the inside micrometer, and the depth micrometer (fig. 97). The outside micrometer is used for measuring outside dimensions, such as the diameter of a piece of round stock. The screw thread micrometer is used to determine the pitch diameter of screws. The inside micrometer is used for measuring inside dimensions, as, for example, the inside diameter of a tube or hole, the bore of a cylinder, or the width of a recess. The depth micrometer is used for measuring the depth of holes or recesses.

d. Selecting micrometer.—All three types of micrometers (*c* above) are usually made so that the longest movement possible between the sleeve and the anvil is 1 inch. This movement is called the "range." The *frames* of micrometers, however, are available in a wide variety of sizes, from 1 inch up to as large as 24 inches for special work. The range of a 1-inch micrometer is from 0 to 1 inch; in other words, it can be used on work where the part to be measured (between the spindle and the anvil) is 1 inch or less. A 2-inch micrometer has a range from 1 inch to 2 inches, and will measure only work between 1 and 2 inches thick; a 6-inch micrometer has a range from 5 to 6 inches, and

will measure only work between 5 and 6 inches thick. It is necessary, therefore, that the mechanic in selecting a micrometer first find the approximate size of the work to the nearest inch, and then select a

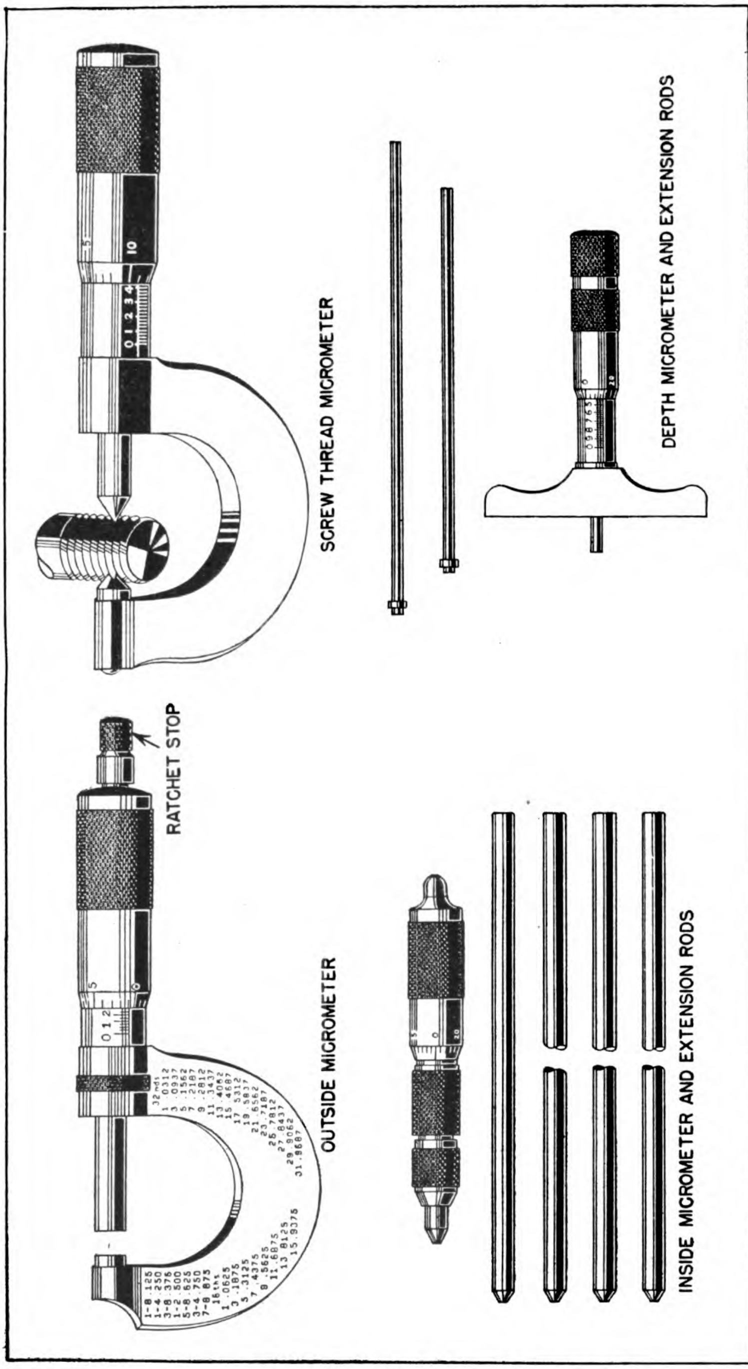

FIGURE 97.—Common types of micrometers.

micrometer that will fit it. For example, to find the exact diameter of a piece of round stock: if it is found by using a rule that the diameter is approximately 5¼ inches, a micrometer with a 5- to

6-inch range would be required to measure the *exact* diameter. Similarly, with inside and depth micrometers, rods of suitable lengths must be fitted into the tool to reach the desired dimension within an inch, after which the exact measurement is read by turning the sleeve. The size of a micrometer is sometimes given as the size of the largest work it will measure and sometimes as its range.

e. Mechanics of micrometer.—The micrometer actually records the endwise travel of a screw during a whole turn or any part of a turn. The micrometer screw has a pitch of 40 threads to the inch; in other words, if the screw is turned 40 times, it will move the spindle exactly 1 inch either toward or away from the anvil. A clockwise turn moves the spindle toward the anvil; a counterclockwise turn moves the spindle away from the anvil. Therefore, by simple arithmetic, it is plain that a single turn of the screw moves the spindle one-fortieth or twenty-five thousandths (0.025) of an inch. (1.000 inch $\div$ 40 = 0.025 inch.)

29. Reading micrometer.—*a.* As explained in paragraph 28*e*, if the sleeve of a micrometer is turned through one complete revolution, the micrometer opens or closes 0.025 inch. Hence, to change the opening 0.001 inch, the sleeve should be turned through only one twenty-fifth of a revolution. To divide the inch into 1,000 parts by using the micrometer, therefore, the problem involved is to count the number of complete revolutions, plus any part of a revolution in twenty-fifths, that the sleeve makes to set the spindle and anvil exactly against the work being measured. For this purpose, the barrel and thimble of all micrometers are marked as shown in figure 98. The revolution line on the barrel should be understood first. It is graduated in lines 0.025 inch apart, so that each complete revolution of the sleeve moves the thimble exactly 0.025 inch along the barrel, or from one graduation to the next. Two complete revolutions move the thimble 0.050 inch, three revolutions 0.075 inch, and four revolutions 0.100 inch ($\frac{1}{10}$ inch). The numbers at every fourth graduation on the revolution line indicate, therefore, tenths of an inch. (4×0.025 inch = 0.100 inch.) Assuming, for example, that the micrometer is closed and the screw is turned counterclockwise through 4 whole revolutions, the edge of the thimble would exactly coincide with the fourth graduation on the revolution line (marked 1) and the micrometer would be opened $\frac{1}{10}$ inch. If the edge of the thimble coincided with the next graduation on the barrel, five revolutions would have been made, so the micrometer would be opened 0.125 inch (0.100 inch + 0.025 inch.) The graduations on the barrel are numbered from 0 to 10. The mechanic should become thoroughly familiar with them before considering the graduations on the thimble.

b. The graduations on the barrel of the micrometer, as explained in *a* above, divide the inch into parts of twenty-five thousandths each; the graduations on the thimble further divide it into single thousandths, by indicating each twenty-fifth of a revolution of the sleeve. It has been shown in *a* above that one twenty-fifth of a revolution opens or closes the micrometer 0.001 inch. When the micrometer is

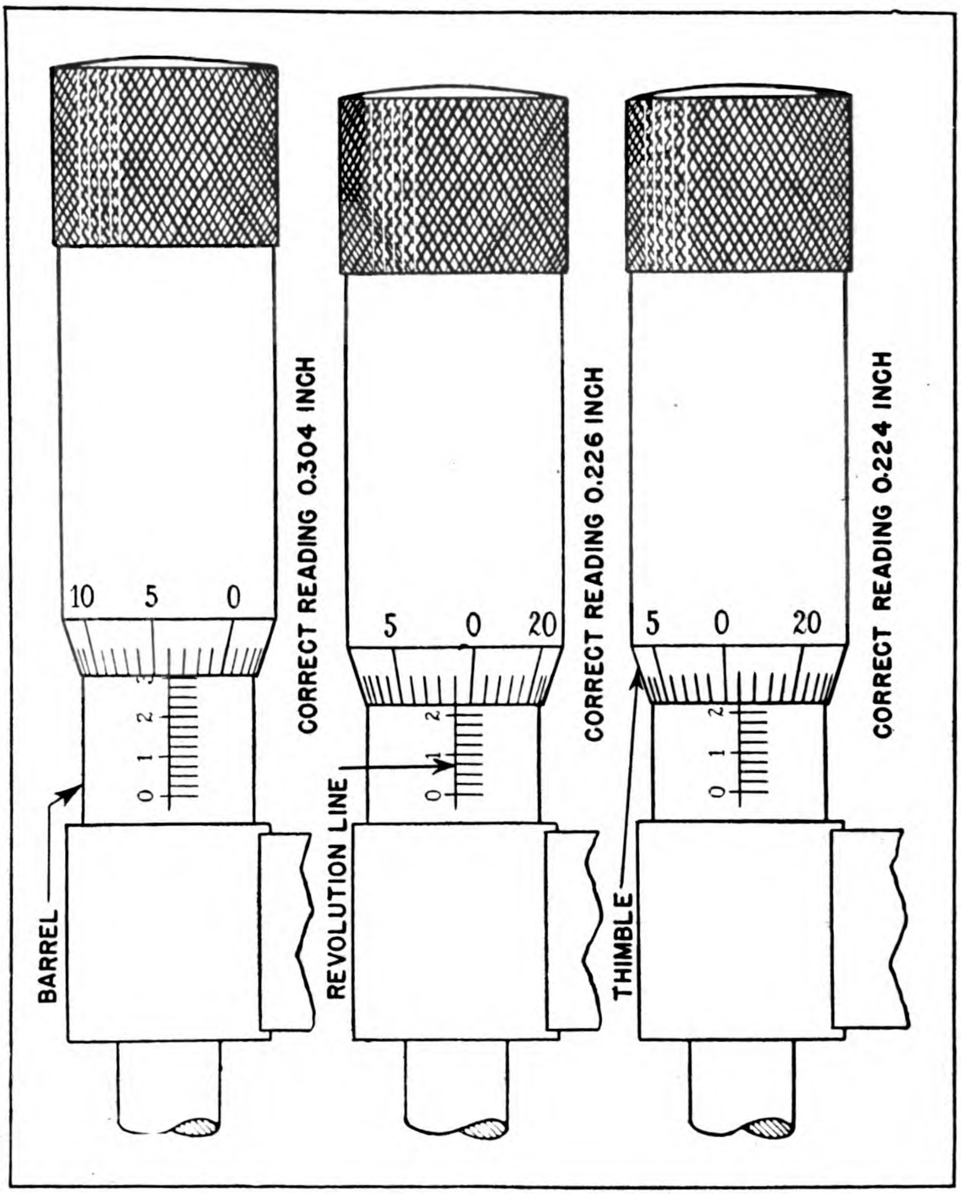

FIGURE 98.—Graduations of micrometer.

closed, the edge of the thimble will coincide with zero on the barrel, and *zero on the thimble will also coincide with the revolution line.* As the thimble is turned, each time a graduation on the thimble passes the revolution line on the barrel, the micrometer opens 0.001 inch.

c. With practice the mechanic can read a micrometer correctly at a glance; however, in learning to do so the following procedure is recommended: using pencil and paper, find the largest number on the revolution line between zero and the edge of the thimble. Use the middle reading in figure 98 as an example; this figure is 2. Write it as 0.200 inch. Then add to it the number of *unmarked* graduations between this figure and the edge of the thimble, which in the example being used is 1, or 0.025 inch. Set this down under 0.200 inch, already written. At this point, if the zero graduation on the thimble coincided with the revolution line, the reading would be complete, as follows:

0.200 inch
0.025 inch
———
0.225 inch, final reading

However, the zero graduation on the thimble and the revolution line do not coincide, so it is necessary that the number of graduations *between* zero on the thimble and the revolution line be added to the 0.225 inch reading. In this example, there is one such graduation. Write this as 0.001 inch, and the complete addition is as follows:

0.200 inch
0.025 inch
0.001 inch
———
0.226 inch, final reading

Therefore, in the example being used, the micrometer is open 0.226 inch. Using a similar procedure with the top reading in figure 98, the result works out as follows:

0.300 inch (largest number on revolution line between zero and edge of thimble)
0.000 inch (number of unmarked graduations between this and edge of thimble)
0.004 inch (number of graduations *on the thimble* between zero and the revolution line)
———
0.304 inch, correct final reading

Using the same procedure again with the bottom reading in figure 98:

0.200 inch (largest number on revolution line between zero and edge of thimble)
0.000 inch (number of unmarked graduations between this and edge of thimble)

0.024 inch (number of graduations between zero *on the thimble* and the revolution line)

0.224 inch, correct final reading

It should be noticed particularly in this last example that the edge of the thimble *appears* to coincide with the 0.025 graduation on the barrel; but if this were true, the zero line on the thimble would coincide with the revolution line, which it does not do. In other words, unless the zero graduation on the thimble coincides with the revolution line, the third figure of the final reading *cannot* be zero.

30. Reading micrometer in ten-thousandths.—Operations are sometimes met with in automotive work where measurement in thousandths of an inch is not accurate enough. Most micrometers have a vernier scale on the barrel for reading measurements in ten-

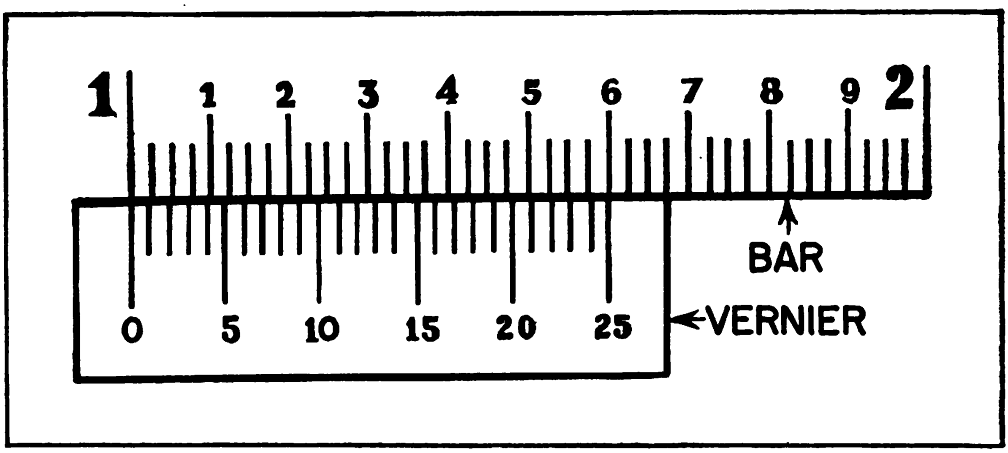

FIGURE 99.—Vernier scale.

thousandths; no mechanic should attempt to use this scale, however, until he has thoroughly mastered the reading in thousandths as explained in paragraph 29.

a. Vernier scale.—The fundamental idea behind the vernier scale is to divide a line of known length into equal parts, and to compare the length of those parts with those on a line the same length as the first one, but divided into one less part. Figure 99 shows a bar 1 inch long divided by graduations into 40 parts so that each graduation indicates one-fortieth of an inch (0.025 inch). Every fourth graduation is numbered (exactly as on a micrometer barrel); each number indicates tenth of an inch (4 × 0.025 inch). The vernier, which slides along the bar, is graduated into 25 divisions which together are as long as 24 divisions on the bar. Consequently, each division on the vernier is 0.001 inch smaller than each division on the bar.

In figure 99, 0 on the vernier coincides with 0 on the bar; the next graduations to the right on both vernier and bar will be 0.001 inch apart; the second pair 0.002 inch apart, and so on, until the graduations coincide again at 25 on the vernier.

(1) The method of reading a vernier caliper is shown in the upper two illustrations, figure 100. In this example, the caliper has been

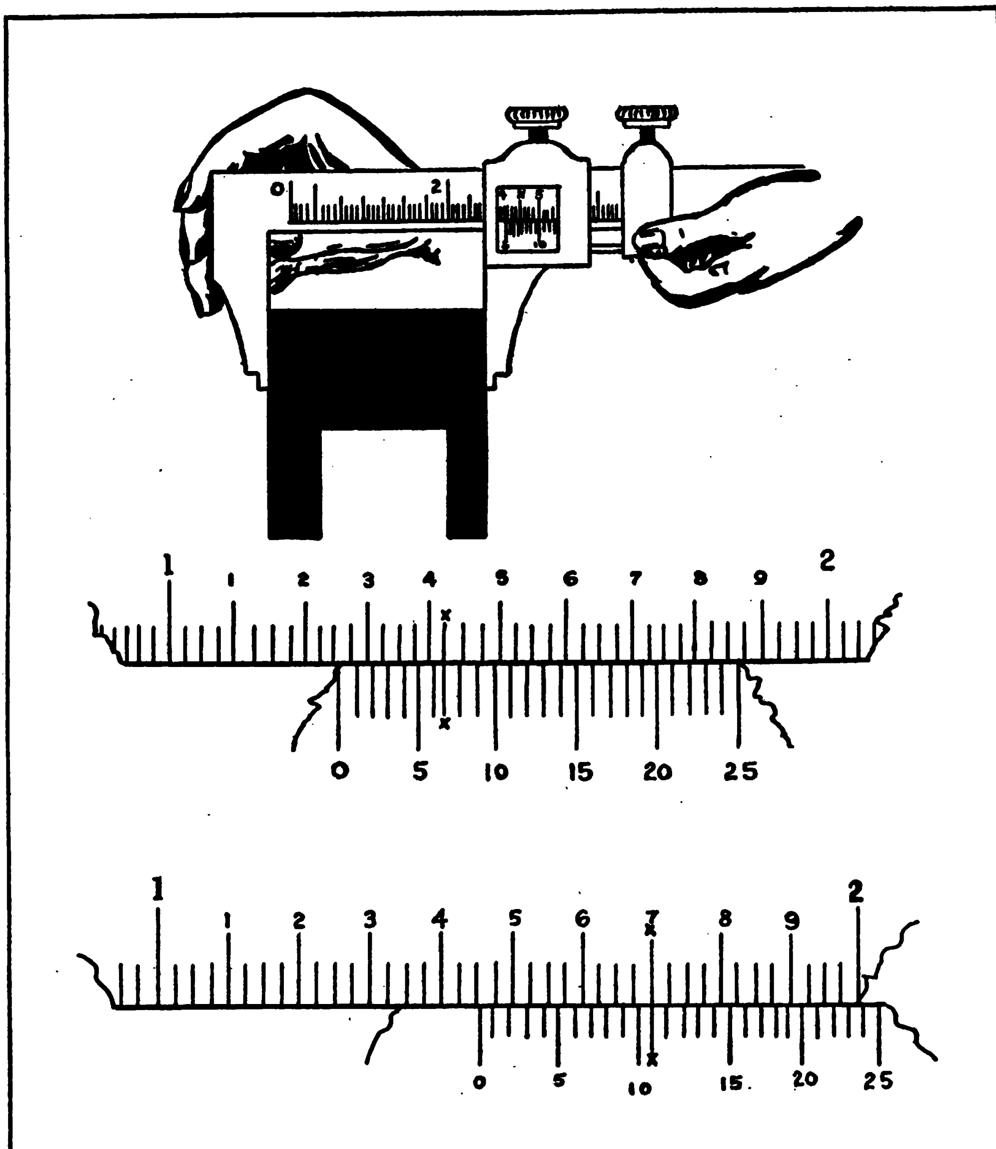

FIGURE 100.—Reading a vernier.

opened to measure a piece of work until the vernier is in the position shown in relation to the bar. To read this measurement, use the following procedure with pencil and paper: First determine on the *bar* how many inches and tenths of inches the caliper has been opened.

In this case the figure is 1.2 inches. Write it as 1.200 inches. To this, add the number of unmarked graduations on the bar between 2 and 0 on the vernier, which in this example is 2. Write it as 0.050 inch (2×0.025 inch). Then, moving the eye to the right from 0 on the vernier in the middle illustration, figure 100, find the graduation on the vernier which coincides with a graduation on the bar; in this example the figure is 7. Write it as 0.007 inch. The addition will then be as follows:

1.200 inches (inches and tenths of inches)
0.050 inch (second step)
0.007 inch (vernier reading)

1.257 inches, final reading

(2) Another example is the lower illustration, figure 100. Proceeding as above, first write the number of inches and tenths of inches on the bar, which in this case would be 1.400 inches. Then add the number of unmarked graduations on the bar between 4 and 0 on the vernier, which is 2, or 0.050 inch. Then, following right from 0 on the vernier, the first graduation that coincides with a mark on the bar is the eleventh. Write this as 0.011 inch. The addition is now as follows:

1.400 inches (first step)
0.050 inch (second step)
0.011 inch (vernier reading)

1.461 inches, final correct reading

b. Vernier scale applied to micrometer.—Figure 101 shows how this principle is applied to the micrometer. The vernier in this case consists of ten divisions marked on the barrel which equal, in over-all dimension, nine divisions on the thimble.

(1) To obtain a correct reading in ten-thousandths in the example in figure 101, first find the reading in thousandths by the method described above, which in this case would give—

0.300 inch (largest number on revolution line between 0 and edge of the thimble)
0.050 inch (number of unmarked graduations on the barrel between 3 and edge of the thimble)
0.019 inch (number of graduations on the thimble between 0 and the revolution line)

0.369 inch, final correct reading

Adding these three figures gives 0.369 inch, which is the correct reading in thousandths. Now to read the vernier, follow across the vernier scale with the eye to the first graduation on it that coincides with a graduation on the thimble. In this example the figure is 5. Write this as 0.0005 inch, and add this to the reading in thousandths already obtained, and the result is—

0.369 inch (reading in thousandths)
0.0005 inch (vernier reading)

0.3695 inch, final correct reading in ten-thousandths

(2) Figure 102 shows two further examples of the vernier scale applied to the micrometer. Following the procedure previously outlined, the example on the left is read thus:

0.4000 inch (tenths of inches on the barrel)
0.0500 inch (2×0.025 inch)
0.0190 inch (19 graduations on the thimble between 0 and revolution line)
0.0000 inch (number on vernier scale which coincides with a graduation on the spindle)

0.4690 inch, final correct reading in ten-thousandths

(3) Use the same method on the example on the right in figure 102. The reading in thousandths is the same as the example on the left; however, the graduation on the vernier which coincides with a line on the thimble is 7. Therefore, add 0.0007 inch to the reading in thousandths, and the correct final reading in this case is 0.4697 inch.

31. Using micrometers.—*a. Measuring flat surfaces.*—Figure 103 shows two uses of the outside micrometer in measuring the distance between two flat surfaces. The mechanic should first of all select the right sized micrometer for the work (in the first case a 0-1 inch size, as the work is less than 1 inch across). The micrometer should be opened far enough to slip over the work freely; then, the micrometer being held in the left hand, the sleeve is turned clockwise until the spindle and anvil lightly touch the work. A very light pressure only is required; if the tool is turned up too tight on the work, the frame will almost surely be sprung out of shape and the reading will be inaccurate. Most micrometers are equipped with a ratchet stop (fig. 96) on the end of the sleeve, which prevents the operator from closing the tool too tightly on the work. This ratchet stop is so made that it will slip and click when a certain amount of pressure is applied to it, and so prevent the spindle from moving

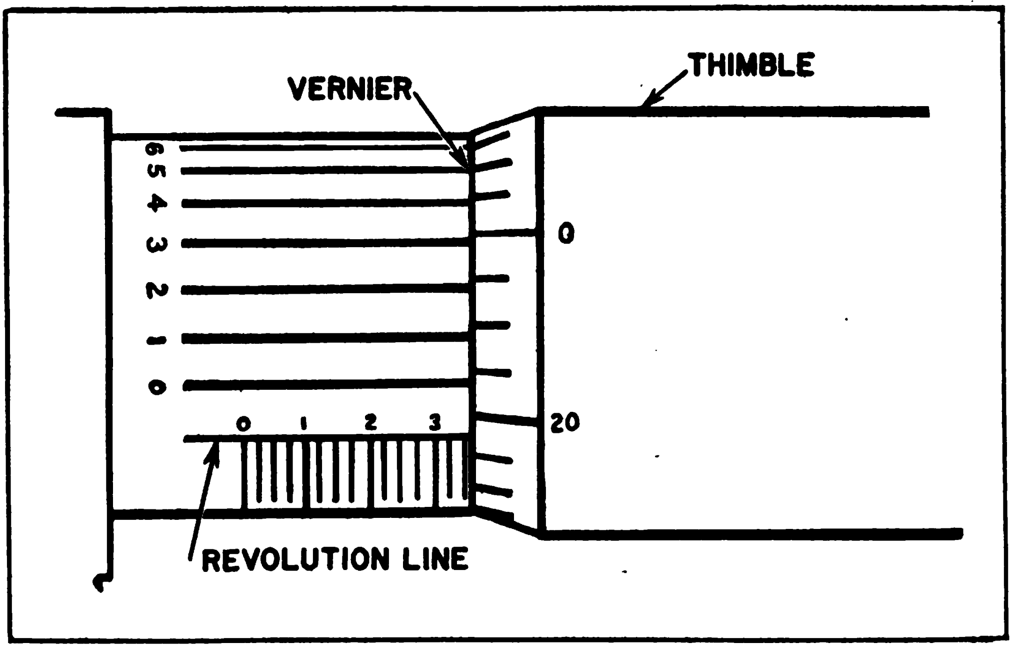

FIGURE 101.—Vernier scale applied to micrometer.

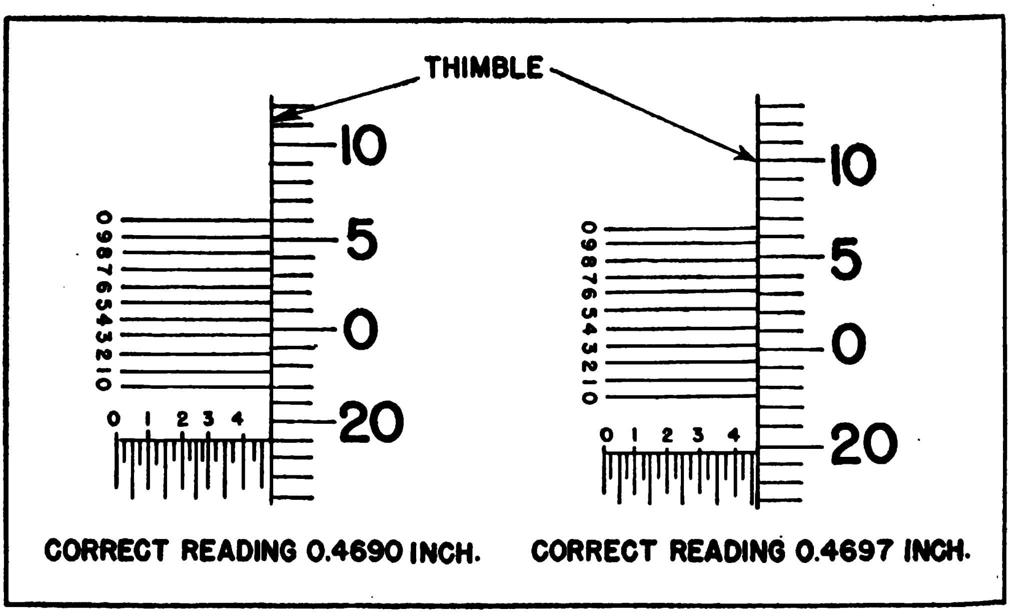

FIGURE 102.—Practice readings of vernier micrometer.

farther. If the micrometer being used is fitted with a ratchet stop, it is recommended that the operator make use of it to avoid damaging the micrometer. Finally, take the reading of the micrometer while it is still on the work. The enlarged view at the left in figure 103 shows the reading of the micrometer, which is 0.625 inch, arrived at by the method previously outlined:

Largest number on the revolution line between 0 and the edge of the thimble, 6 or	0. 600 inch.
Number of unmarked graduations on the revolution line between 6 and the edge of the thimble, 1 or	0. 025 inch.
Number of graduations on the thimble between 0 and the revolution line	0. 000 inch.
Correct reading	0. 625 inch.

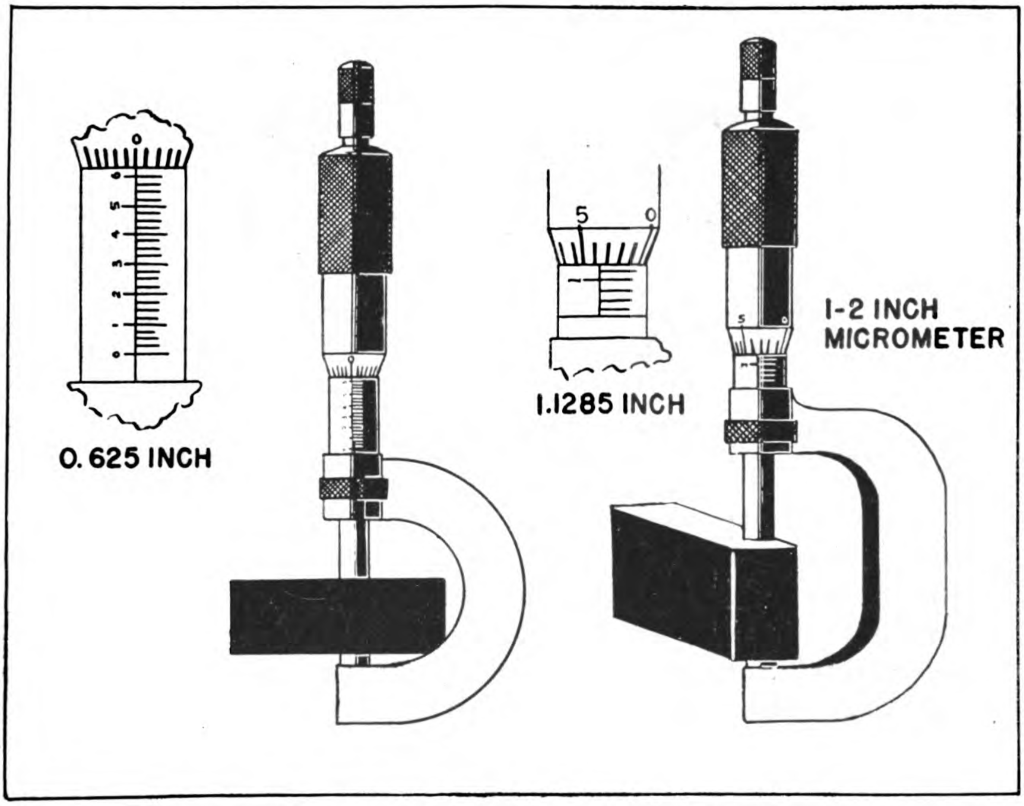

FIGURE 103.—Measuring flat surfaces with outside micrometer.

At the right in the same figure the reading is 0.1285 inch figured by the usual method recommended:

Largest number on the revolution line between 0 and the edge of the thimble, 1 or	0.100 inch.
Number of unmarked graduations on the revolution line between 1 and the edge of the thimble, 1 or	0.025 inch.
1- to 2-inch range micrometer, add	1.0000 inch.
Number of graduations on the thimble between 0 and the revolution line, 3 and (approximately) ½, or	0.0035 inch.
Correct reading	1.1285 inches.

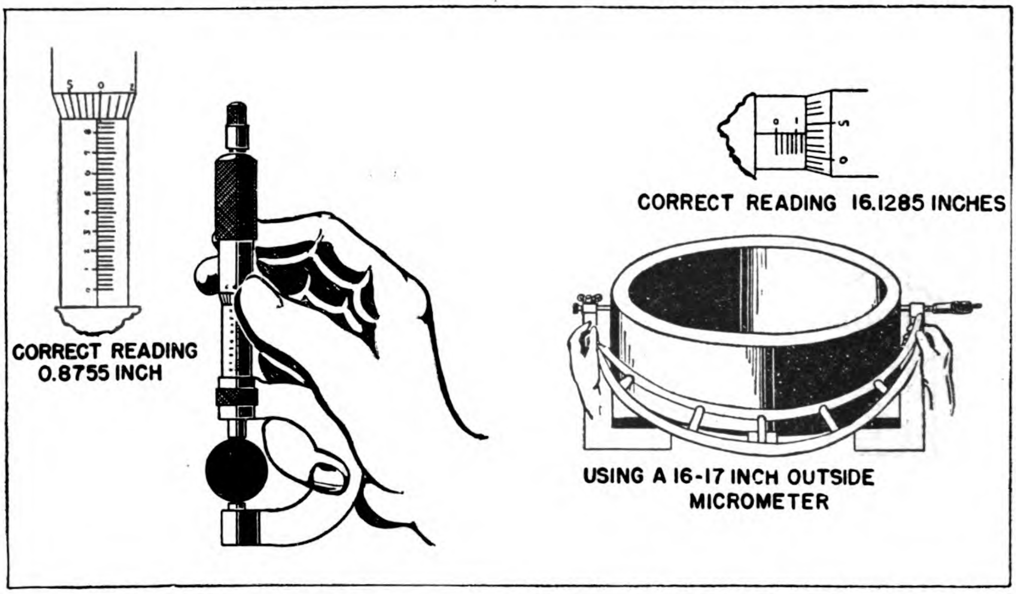

FIGURE 104.—Measuring round stock with outside micrometer.

b. Measuring over round surface.—Figure 104 shows two operations in measuring the diameter of round stock. When the correct size micrometer has been selected, the procedure is the same as in measuring across a flat surface. Care must be used to see that the work is measured at points exactly opposite each other; this can be done by sliding the micrometer back and forth across the piece until the right "feel" is obtained.

c. Measuring inside diameters.—(1) Figure 105 shows the correct position of an inside micrometer for taking the inside measurement of a round piece of work, such as the diameter of a gasoline engine cylinder.

Proceed by first finding the approximate diameter with a rule; then select an extension rod of the proper length and attach it to the micrometer. The number of inches a rod will measure is stamped on each one. Be sure both the rod and the micrometer are thoroughly clean, that the rod is turned up the full distance possible, and that it is securely in place. Neglect of any of these precautions may result in an incorrect measurement. When the extension rod has been prop-

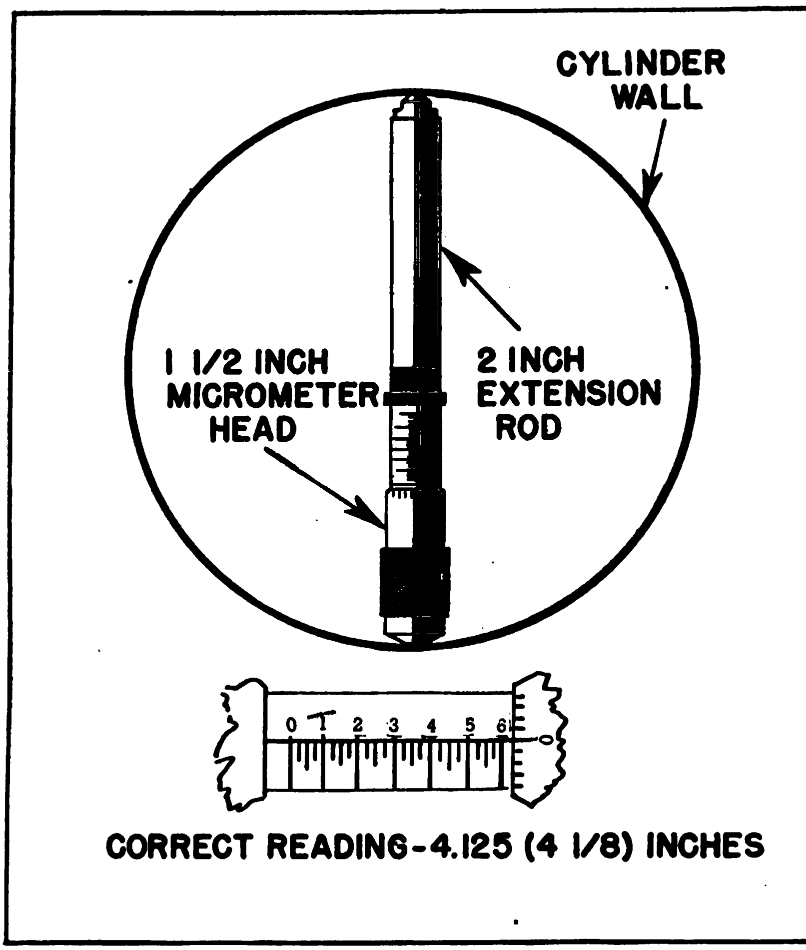

FIGURE 105.—Measuring inside diameter with micrometer.

erly set, place the end of the rod against one side of the hole and turn the sleeve of the micrometer until the head barely touches the other side at a point *exactly opposite*. Then read the dimension while the micrometer is still in the work. Never let the micrometer bear heavily enough to hang in the work with the hands removed from it.

(2) Another method commonly used for measuring smaller work, where an inside micrometer will not fit conveniently, is to use a telescoping gage (fig. 106). The telescoping gage should be adjusted in

the work until it exactly touches points directly across from each other; it is then locked by turning the stem; then it is removed and the dimension is measured with an outside micrometer. For very small holes, the type of inside micrometer shown in figure 107 is convenient; the illustration shows clearly its use and the correct method of reading the measurement obtained with it.

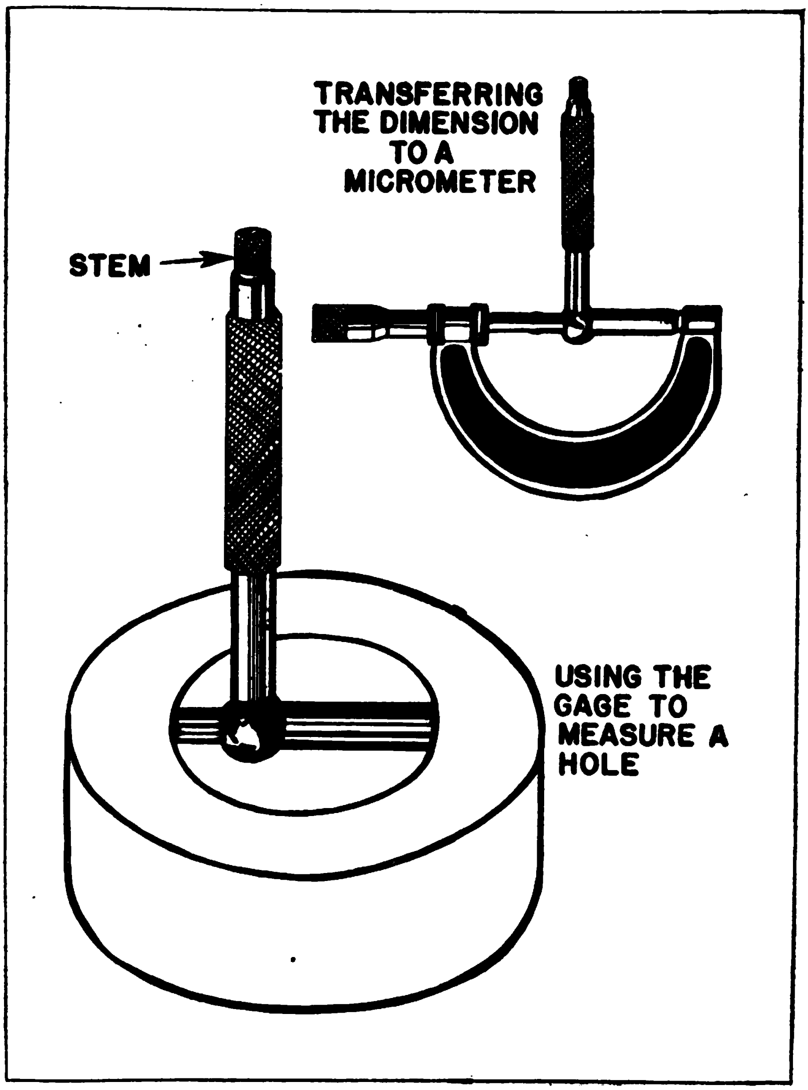

FIGURE 106.—Telescoping gage.

d. Measuring depth of recesses.—Figure 108 shows a depth micrometer used to measure the depth of a hole. The mechanic should first be sure that the surface of the work around the top of the hole is clean and smooth; any burs should be removed with a fine, smooth, flat file. With the base of the micrometer set firmly against the flat surface, as shown, turn the sleeve *clockwise* until the pin just touches

the bottom of the hole. If the micrometer is equipped with a ratchet stop, it should be used. The measurement can then be read in the usual manner.

32. Adjustment and use of micrometers.—*a. Adjustment.*—Micrometers often get out of adjustment, and should not be used until set back to their proper position. If the frame has been badly bent it must be straightened before any adjustment is attempted; if

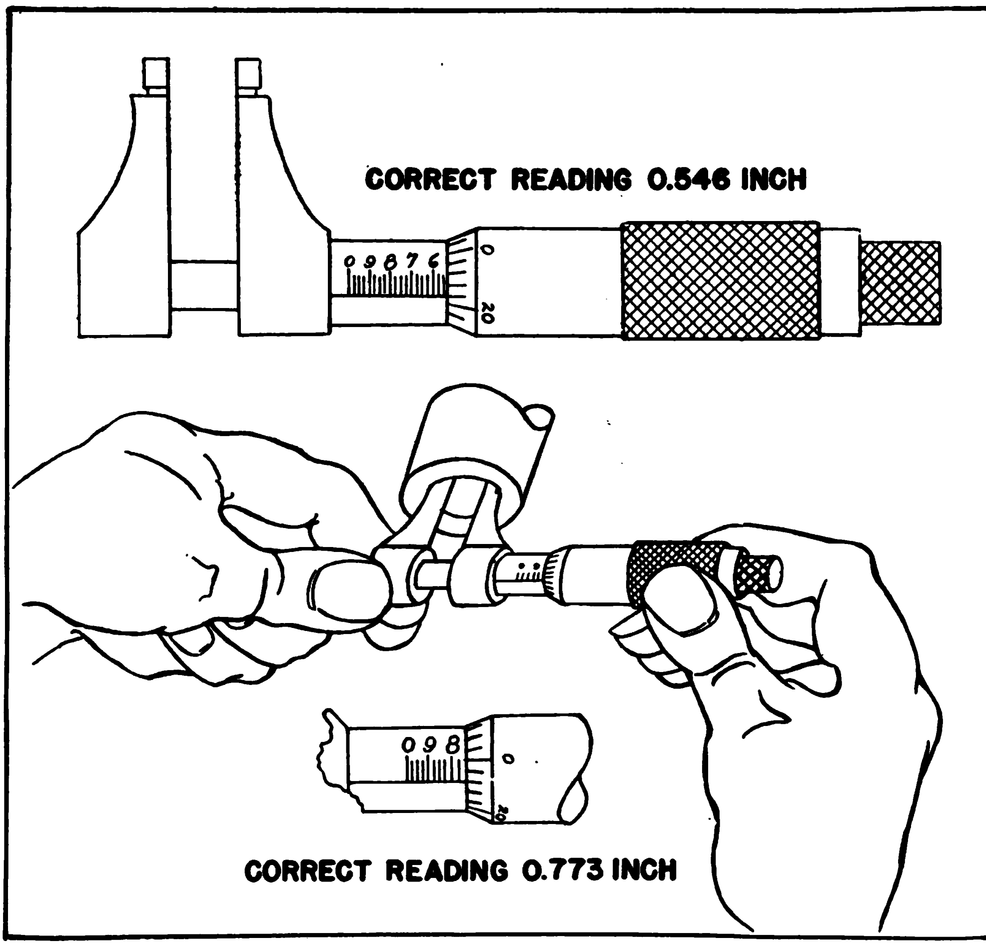

FIGURE 107.—Inside micrometer for small holes.

it is sprung only 0.002 or 0.003 inch, the error can be compensated by the adjusting arrangements. The two adjustments possible on any micrometer are adjustment for wear of the screw and adjustment for position of the spindle.

(1) *Adjustment for wear of screw.*—Constant use of a micrometer will slightly wear the threads of the screw. In order to adjust the tool to compensate for this wear, proceed as follows:

(*a*) Turn the thimble counterclockwise until the compression nut at the top of the hub can be reached with a spanner wrench provided with the tool.

(*b*) Turn the compression nut a slight amount to the right and try the screw to see if it is tight.

(*c*) If it is not tight, continue to turn the compression nut until the screw has a firm, easy "feel."

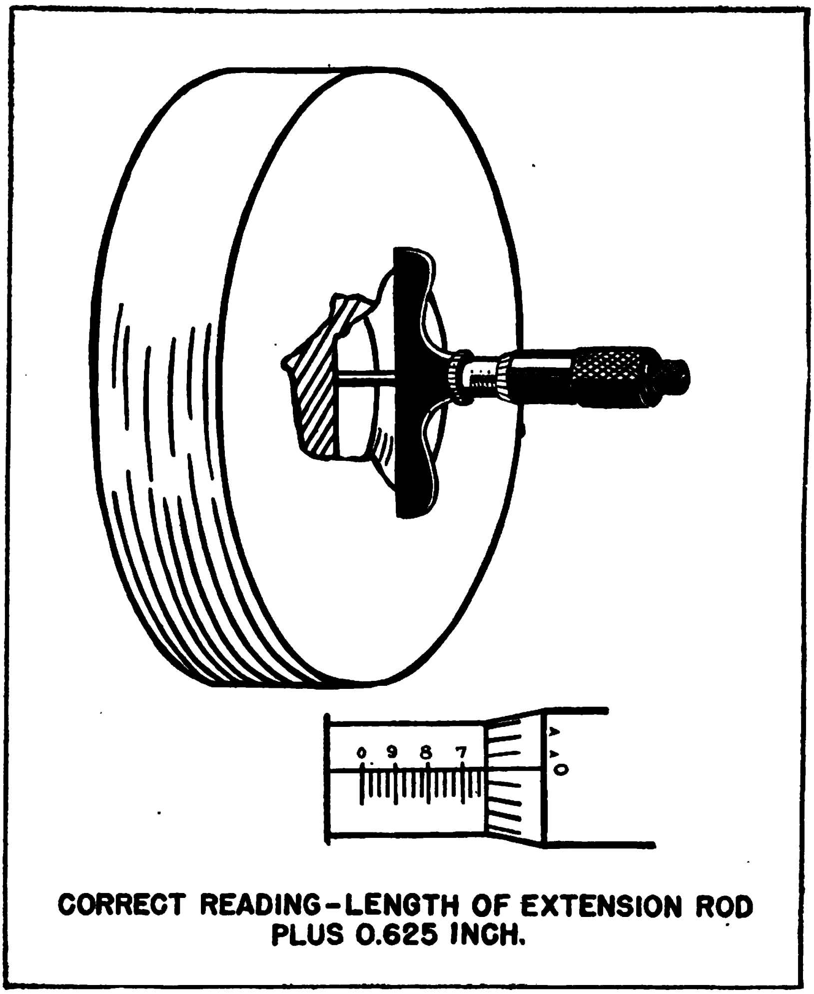

FIGURE 108.—Depth micrometer.

(2) *Adjustment for position of spindle.*—To compensate for wear on the end of the spindle of a 1-inch micrometer, proceed as follows:

(*a*) Loosen the cap with a wrench; this will make it possible to turn the thimble and spindle independently of each other. Hold the spindle stationary, and turn the thimble counterclockwise about one-quarter of a turn. Then let go of the spindle and turn the thimble to the correct zero reading. Test this reading as follows:

(*b*) Let go of the thimble, and back the spindle away from the anvil with the fingers, then, again turning the thimble and letting go of the spindle, close the micrometer; if 0 on the edge of the thimble coincides with the revolution line, and the edge of the thimble coincides with the zero graduation on the barrel, the micrometer is properly set. If not, continue adjusting until they do coincide, and tighten the cap.

(*c*) To adjust a micrometer larger than a 1-inch size, a gage block must be used between the anvil and spindle to test for the correct zero reading.

b. Use.—Normal use of the micrometer does not involve danger to the operator, but certain precautions should always be taken to prevent damage to the tool itself, since it is a delicate instrument. Most micrometers are ruined by being closed too tightly on the work. Only a very light pressure is needed to obtain an accurate measurement. If the micrometer has a ratchet stop, *it should be used.* The tool should never be swung back and forth by the thimble to secure the correct adjustment; always hold the frame stationary and adjust the tool by turning the sleeve. Both the micrometer and the surfaces being measured must be clean to give accurate readings. In using large micrometers (24 to 36 inches) care is needed to see that the frames are not handled roughly or sprung out of shape. When using the larger micrometers in cold weather, it is good practice to use a piece of cloth or waste between the hand and the frame, as the heat of the hand may expand the frame enough to cause a variation in the reading.

33. Gage blocks.—*a. General.*—Gage blocks are rectangular pieces of tool steel, having two measuring surfaces which are flat, parallel with each other, and a predetermined distance apart; this distance being accurate to within 0.000002 (two millionths) of an inch. These blocks are so exactly machined, finished, and lapped that if the measuring surfaces of any two of them, when thoroughly clean, are slid together with a slight inward pressure, they will adhere to one another as though magnetized. Johansson type gage blocks (commonly called jo-blocks by machinists) are available in three grades of accuracy:

(1) Laboratory set, AA quality, accurate to 0.000002 inch (millionths).

(2) Inspection set, A quality, accurate to 0.000004 inch (millionths).

(3) Working set, B quality, accurate to 0.000008 inch (millionths).

b. Working set.—A full working set of gage blocks is made up of 81 blocks, accurate to within 0.000008 inch. The set consists of four series of sizes, as follows:

(1) *First series.*—9 blocks ranging in size from 0.101 inch to 0.1009 inch in steps of 0.0001 inch (0.1001 inch, 0.1002 inch, 0.1003 inch, etc.).

(2) *Second series.*—49 blocks, ranging in size from 0.101 inch to 0.149 inch, in steps of 0.001 inch (0.101 inch, 0.102 inch, 0.103 inch etc.).

(3) *Third series.*—19 blocks, ranging in size from 0.100 inch to 0.950 inch, in steps of 0.050 inch (0.100 inch, 0.150 inch, 0.200 inch, etc.).

(4) *Fourth series.*—4 blocks, 1 inch, 2 inches, 3 inches, and 4 inches.

c. Use.—By sliding different sizes of blocks together, the machinist can obtain any measurement in ten-thousandths of an inch from 0.200 inch to 12.00 inches, and in thousandths of an inch from 0.100 inch to 12.00 inches. For example, a 0.124 inch block (second series) slid to a 0.750 inch block (third series) will give an over-all measurement of 0.874 inch. If a 0.1003 inch block (first series) is added to these, the measurement will increase to 0.9743 inch. Similarly, if it were desired to combine gage blocks to a size of 5.2721 inches, the following combination could be used:

0.1001-inch block (first series)
0.149 -inch block (second series)
0.123 -inch block (second series)
0.900 -inch block (third series)
4.000 -inch block (fourth series)

5.2721 inches, total measurement

It is of course possible to use several other combinations of blocks to obtain 5.2721 inches, but as a rule it is best to use as few blocks as possible. The mechanic should become familiar with the sizes of the four series, and practice making up various combinations of them to obtain specific measurements.

34. Use of gage blocks.—Gage blocks are most commonly used in the shop for checking the accuracy of other gages (as for instance a micrometer), although it is practical to use them directly on a piece of work to be measured. For example, if the machinist desired to check the accuracy of a 0.625 inch (5/8-inch) snap gage, the procedure should be as follows: Select blocks that will combine to a total size of 0.625 inch, in this case a 0.500-inch block and a 0.125-inch block. Wipe the measuring surfaces clean on the hand, wrist, or on a piece of chamois, and slide them together so that they adhere. If the blocks will then *exactly* fit the opening of the snap gage being checked, it is accurate; if not, it should be adjusted before being used. Gage

block accessories are available which augment the uses of the blocks for a great variety of extremely precise measuring operations. Gage blocks are also used directly on machines for many operations; for example, for setting compound slides.

SECTION IV

USE AND CARE OF POWER TOOLS

35. Electric drill.—*a. General.*—The process of drilling holes in metal with an electric drill is similar to drilling by hand (par. 11) ex-

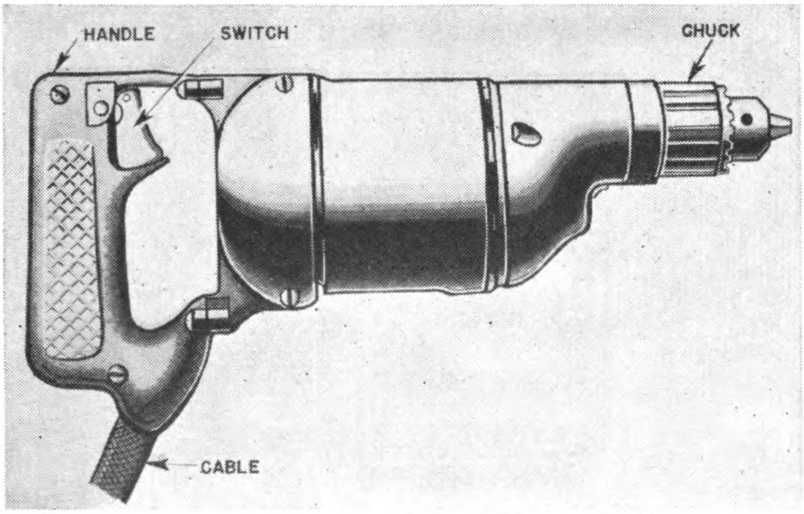

FIGURE 109.—Three-eighths inch electric drill.

cept that the power for turning the drill is furnished by an electric motor instead of by the operator. In automotive work done in the shop it is often possible to mount the electric drill in a drill stand, and the mechanic should become accustomed to using the stand as well as the electric drill itself. Electric drills commonly used for automotive work have capacities for drilling holes in steel from $1/16$ inch up to 1 inch in diameter. Figure 109 shows a popular type of electric drill. They are equipped with pistol grip or spade (closed) handles; the larger drills usually have an extra handle so that they can be held in both hands during the drilling operation. Ordinarily, straight shank twist drills are used in electric drills, being secured in a key type geared chuck (fig. 110) which automatically centers the drill shank in the tool.

Many electric drills can be fitted with attachments for driving screws, rotating small grinding wheels, drilling at right angles, and so on.

b. Use of electric drill.—In drilling metal with an electric drill, the mechanic must first be sure that the diameter of the hole to be drilled is within the capacity of the tool. Electric drill sizes usually indicate the largest diameter the tool will drill in steel; for example, a ½-inch electric drill is intended to drill holes up to and including ½ inch in diameter, and no larger. If used for a ⅝-inch hole, for instance, the work will overload the motor and probably stall the tool. It is better practice, where possible, to use a drill which has the capacity to drill somewhat larger holes than the work calls for. The location of the hole should be carefully marked and started with a

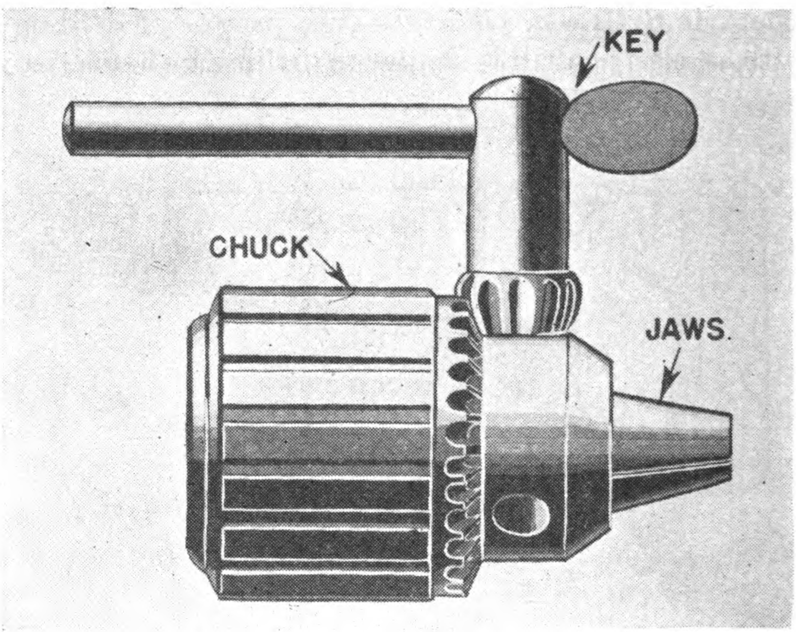

FIGURE 110.—Key type geared chuck.

center punch, exactly as when drilling by hand; then, *with the motor running*, insert the point of the drill into the punch mark and start drilling. Care must be used to hold the electric drill at the right angle so the hole will be straight; with the tool held in that manner, exert a light pressure and continue drilling. If the hole goes clear through the work, relieve this pressure when the point of the drill begins to break through until the hole is completed. Finally, withdraw the drill from the hole, pulling it *straight back*, and then shut off the motor of the tool. The mechanic should remember that twist drills do not pull themselves into the work; they must be fed by pressure, and this pressure must be exerted by the operator of an electric drill in

exactly the same way as if drilling entirely by hand. The only effort saved the operator by the electric drill is that of *turning.*

c. Use of drill stand.—The drill stand aids in accurately locating and maintaining the direction of a hole to be drilled as well as providing the operator with an easy control for feeding the drill into

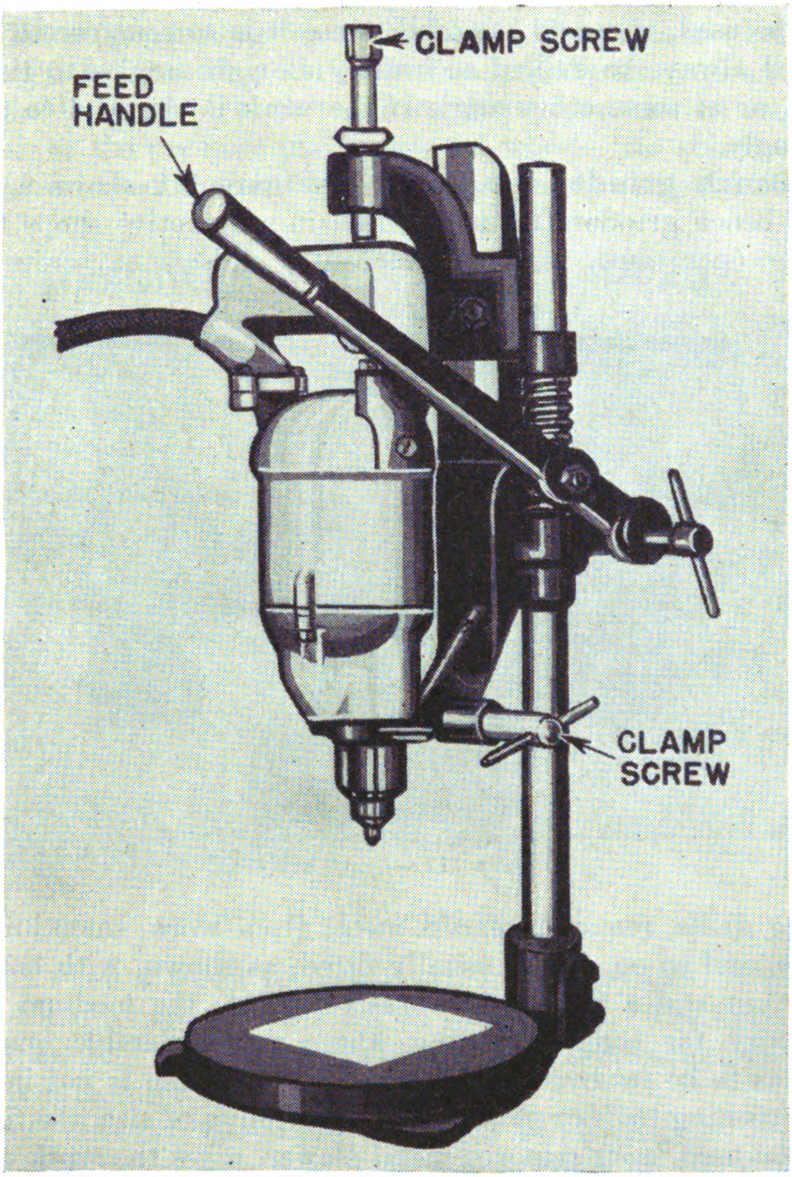

FIGURE 111.—Stand for electric drill.

the work. A common type of drill stand is shown in figure 111, with a ½-inch electric drill fitted to it. A lever is provided on such a stand so the operator can feed the drill into the work with either very heavy or comparatively light pressure. When a drill stand is used, the work is placed on the table provided and the tool brought

down on it by means of the handle; the location of the hole, therefore, must be placed under the drill, rather than the drill put to the location, as when drilling by hand. The work should be securely fastened to the table with clamps, and the drill fed into it by means of the lever with sufficient pressure to cut, but not enough to cause the drill to overheat, or the motor to stall. For accurate work, the drill stand should be used, if one is available, since it is so constructed that the hole will always be drilled accurately at right angles to the work's surface, or at some other angle if the work is clamped to the table accordingly.

36. Bench grinder.—*a. General.*—Figure 112 shows a common type of bench grinder frequently used in automotive shops for hand grinding operations, such as sharpening chisels or screw drivers,

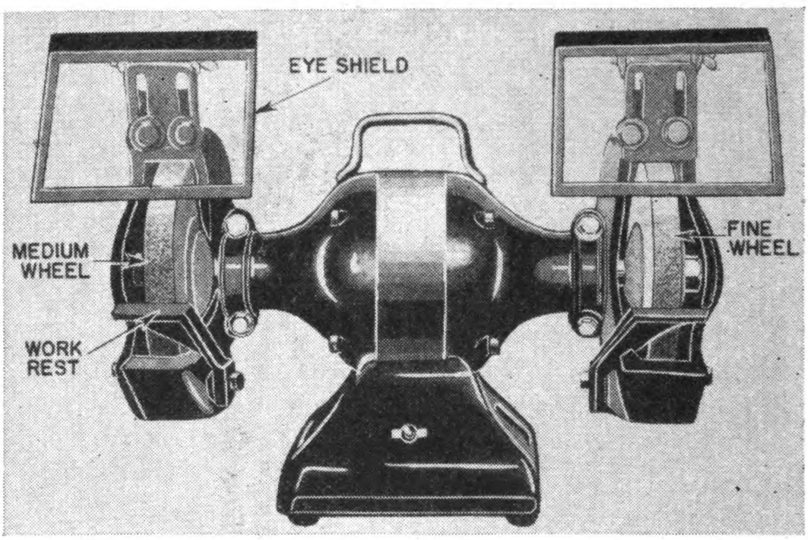

FIGURE 112.—Bench grinder.

grinding drills, removing excess metal from work, smoothing metal surfaces, and so on. It is usually fitted, as shown, with both a medium grain and a fine grain abrasive wheel; the medium wheel is satisfactory for rough grinding where a considerable quantity of metal has to be removed, or where a smooth finish is not important. For sharpening tools or grinding to close limits of size, the fine wheel should be used, as it removes metal slower, gives the work a smooth finish and does not generate enough heat to anneal cutting edges. When a deep cut is to be taken on work or a considerable quantity of metal removed, it is often practical to grind with the medium wheel first and finish up with the fine wheel. The wheels are removable, and most bench grinders are so made that wire brushes, polishing wheels, or buffing wheels can be substituted for them.

b. Use and care of bench grinders.—Before using the bench grinder for sharpening tools, the mechanic should review, in section II, the angles at which the cutting edges should be ground (for example, 60° for cold chisels, 59° for drill points, etc.). The work should be held firmly at the correct angle on the rests provided and fed into the wheel with enough pressure to remove the desired amount of metal without generating too much heat. The rests are removable, if necessary, for grinding odd-shaped or large work. As a rule, it is not advisable to grind work requiring heavy pressure on the side of the wheel, as the pressure may crack the wheel. As abrasive wheels become worn, their surface speed decreases and reduces their cutting

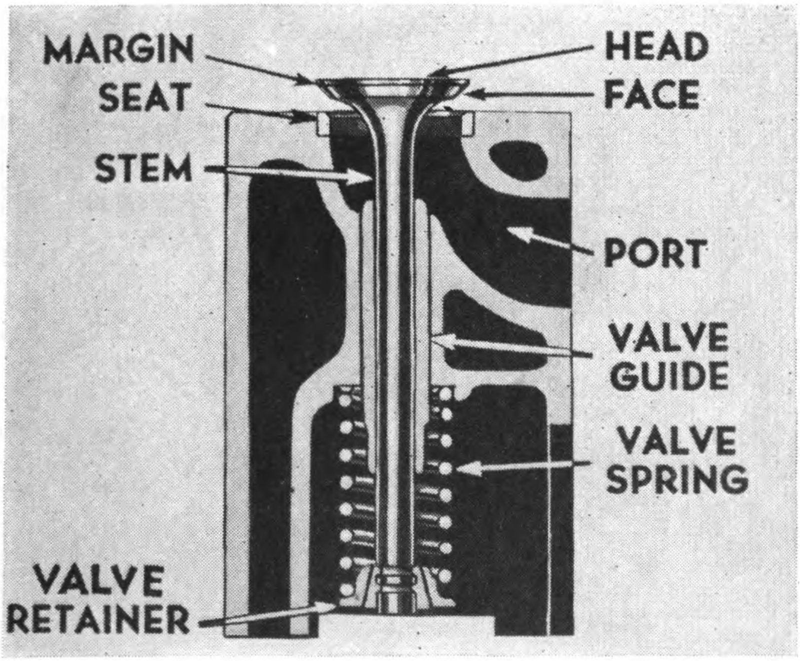

FIGURE 113.—Valve and valve seat.

efficiency; when a wheel becomes worn in this manner, it should be discarded and a new one installed on the grinder. The bearings and motor of the tool are provided with cups for lubrication, as directed by the manufacturer of the tool.

c. Safety precautions.—Before using a bench grinder, make sure that the wheels are firmly held on the spindles by the flange nuts and that the work rests are tight. Wear goggles, even if eye shields are attached to the grinder, and bear in mind that it is *unsafe ever to use a grinder without wheel guards.* Also, remember that it is easy to run your thumb or finger into the wheel.

37. Valve grinding tools.—*a. General.*—Valve grinding is so common an operation in motor vehicle maintenance that the mechanic

should become familiar with the operations involved in it and the tools ordinarily used to perform the operations. Figure 113 shows how the valve of an internal combustion engine is arranged to close by fitting against a seat in the cylinder block; it is absolutely necessary for efficient operation of the engine that the face of the valve and the seat be ground to an extremely close fit to prevent gas leakage. The maintenance operations necessary to assure this fit include grinding both the face of the valve and the valve seat, and a lapping operation. Most shops are equipped with the following electric tools to do this work accurately: a valve refacing tool; a valve seat grinder;

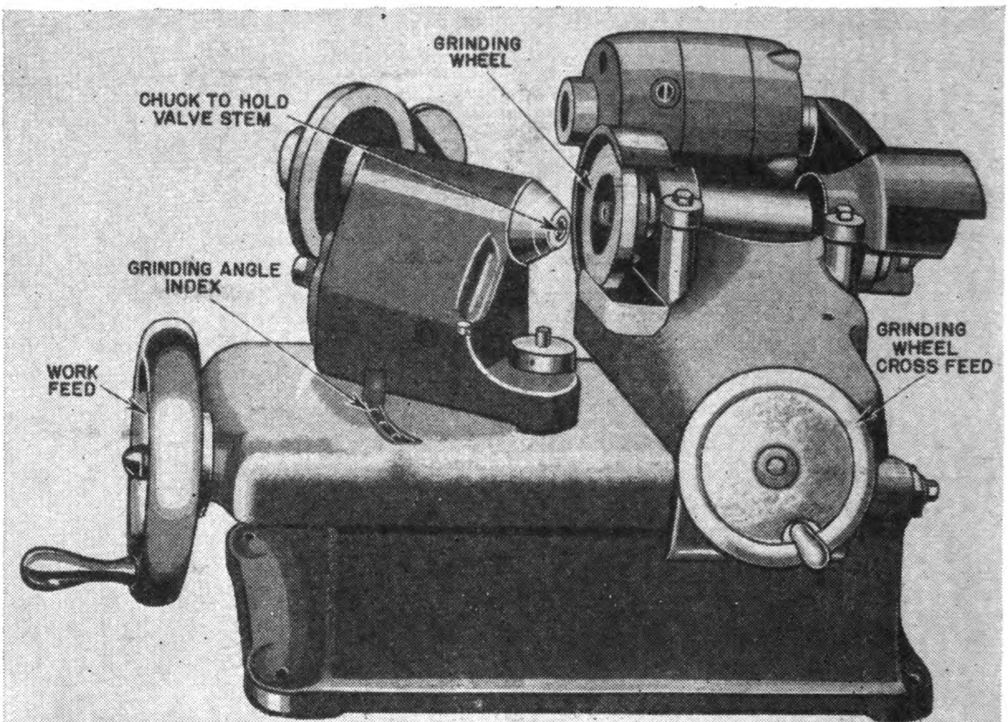

FIGURE 114.—Electric valve refacing tool.

and a valve lapper. The three operations together are usually referred to as a "valve grinding job."

b. Valve refacing tool.—Figure 114 shows a common type of electric valve refacing tool. Actually, this is a grinder so arranged that the angle of the valve face can be accurately set and maintained throughout the grinding operation. The abrasive wheel used produces a very smooth finish on the hard valve material. In operation, both the wheel and the work revolve but at different speeds. The valve stem is secured in a chuck which can be set at the necessary angle. Some valve refacers are equipped for wet grinding, in which a coolant (usually soda water) is run on the wheel and

the work while being ground. Wet grinding enables the mechanic to save time by taking deeper cuts into the work without generating too much heat and produces an unusually smooth finish on the face of the valve.

c. Valve seat grinder.—When the valve face is ground, it is also necessary to grind the valve seat in the cylinder block of the engine. For this purpose a valve seat grinder, similar to the one shown in

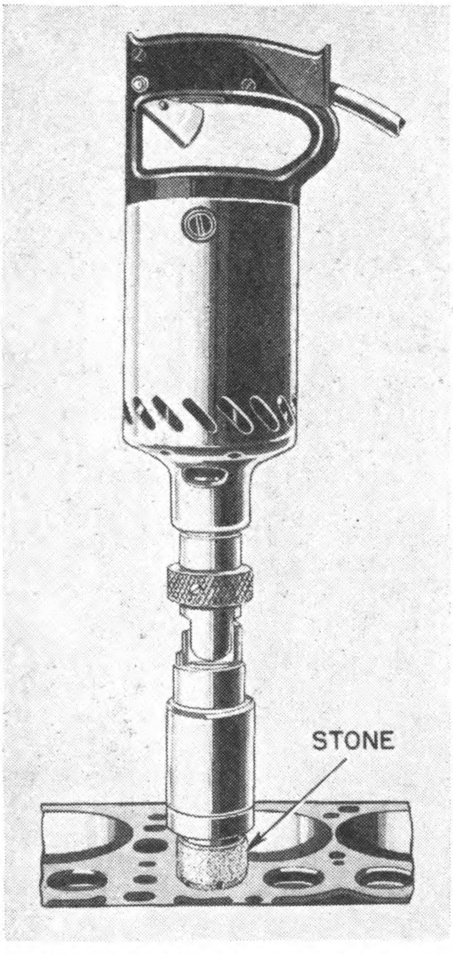

FIGURE 115.—Electric valve seat grinder in use.

figure 115, is generally used. The abrasive wheels used with these tools are specially shaped to grind the valve seat to a correct angle for the valve face, and the tool is equipped with a device which lifts the wheel off the work at each revolution, clearing the stone of ground metal and reducing wear of the stone as well as speeding up the job. Most mechanics grind valve seats first with a coarse stone, and finish up with a special finishing stone which gives the work a very smooth and accurate surface. A stand is provided for

dressing the stones with a diamond. It is very important that the face of the stone be kept true for accurate work. Interchangeable, self-centering pilots are generally used to take care of wear in the valve guides, but they must be of the same nominal size as the valve stems to fit the guides accurately.

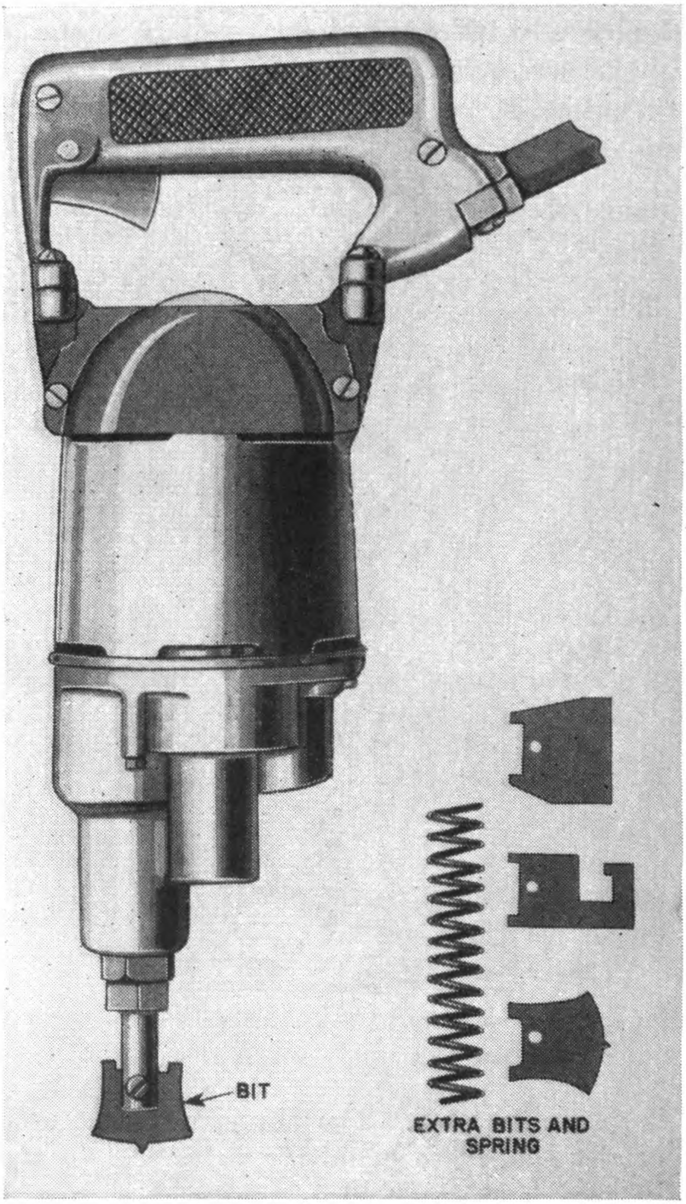

FIGURE 116.—Electric valve lapper.

d. Valve lapper.—When both the valve face and the seat have been ground, as described above, it is necessary to lap the surfaces to obtain a final effective fit of the valve face in the seat. Lapping is generally described as the process of grinding a surface by rub-

bing it against another surface with an abrasive between them. Lapping produces the smoothest finish on metal of any grinding operation. In lapping valves, the valve face is covered with an abrasive and oscillated against the valve seat until a practically perfect fit is obtained between them. The abrasive used is generally

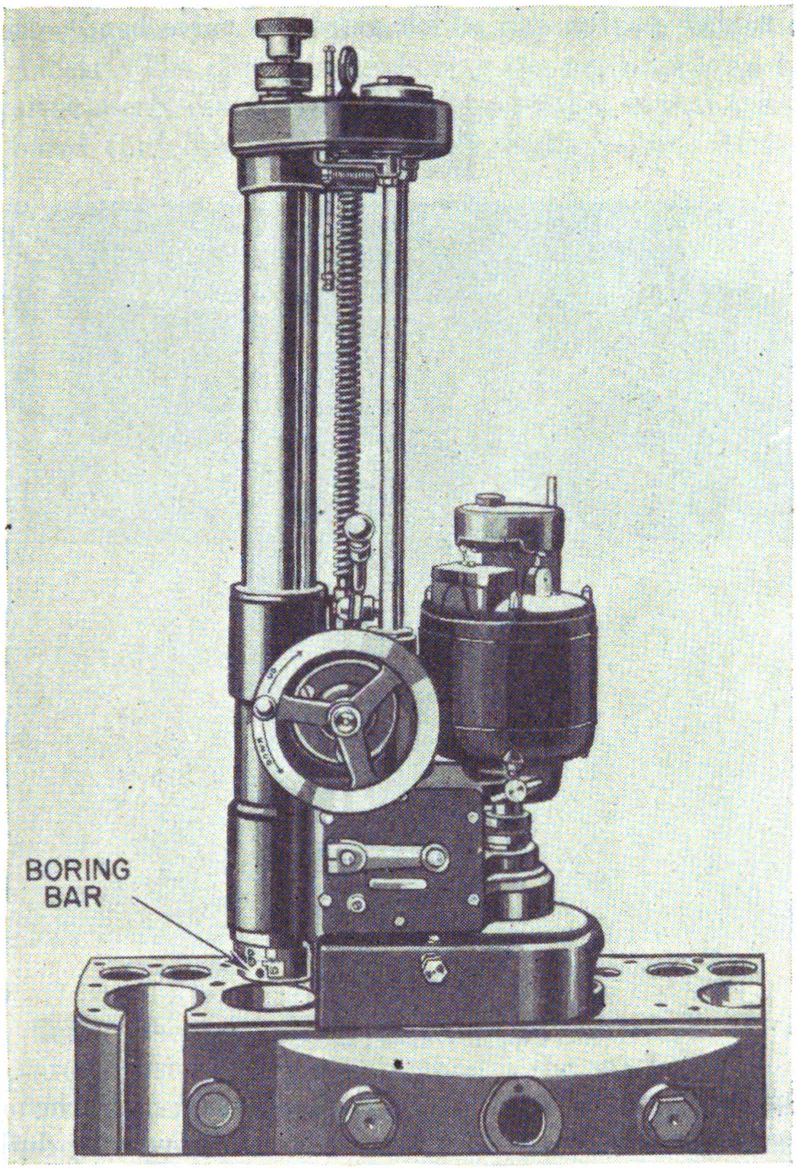

FIGURE 117.—Cylinder boring machine.

a prepared valve grinding compound. This lapping can be, and often is, done by hand; but a valve lapping machine makes the operation much easier and faster. In lapping a valve, the valve is inserted into its guide in the cylinder block of the engine and moved back and forth against the seat with light pressure. The

valve should be lifted from the seat every few strokes; usually the operator inserts a light spring under the valve head to make it lift from the seat automatically when the pressure is relieved. The electric valve lapper (fig. 116) is fitted with a bit which fits into a slot provided in the head of the valve to provide the turning connection. If the valve does not have a slot, the lapper can be equipped with a rubber suction cup which grips the valve head. In lapping,

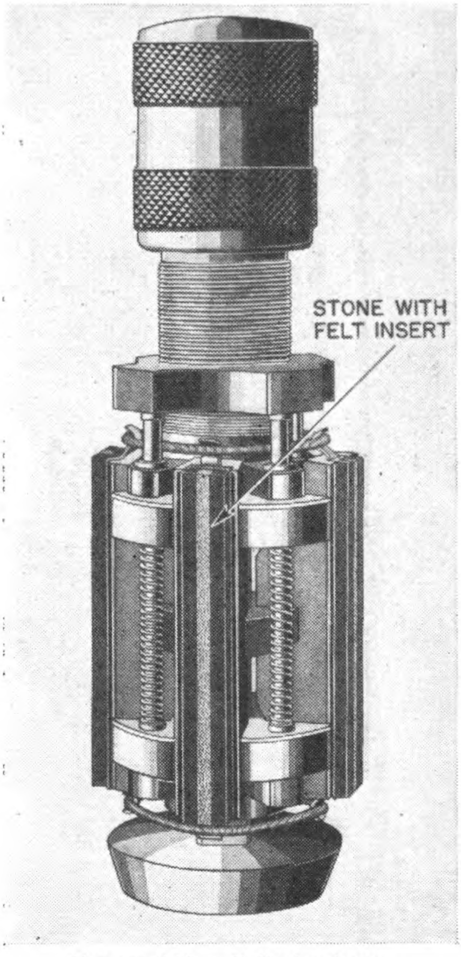

FIGURE 118.—Cylinder hone.

grinding compound should be used generously, and the operation continued until the valve face and the seat show as a dull ring.

38. Cylinder boring and honing tools.—*a. General.*—It is often necessary in automotive maintenance work to rebore the cylinders of an engine which have become worn out of round. An electrically driven cylinder boring machine, such as the one shown in figure 117, is usually used for this operation. This tool bores the inside diameter of the cylinder round and to within 0.001 inch of

a predetermined diameter. A final smooth finish can be obtained on the cylinder wall by using a cylinder hone, shown in figure 118.

b. Use of cylinder boring machine.—The cylinder boring machine is made to clamp solidly to the cylinder block of the engine by means of an anchoring device which hooks to the bottom of the block through the cylinder next to the one being ground. One such anchoring device is illustrated in figure 119, installed on a cylinder block. The object in anchoring the machine is to have the boring bar properly centered and solidly mounted so that the cylinder will be bored the right size and on the right center. It is impos-

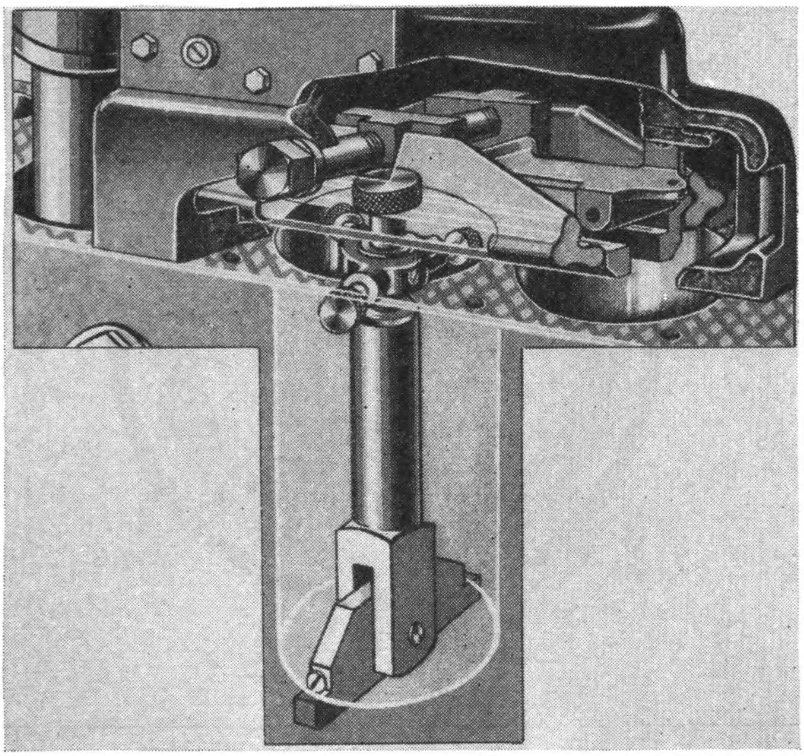

FIGURE 119.—Set-up of cylinder boring machine.

sible to detail the procedure, because the machines of different manufacturers require different methods; the mechanic should follow whatever instructions are provided by the manufacturer. This applies to cylinder hones as well; the manufacturer's manual will provide the mechanic with detailed directions for setting the hone to the exact diameter desired and enable him to hone cylinder walls to a smooth, accurate finish. All types employ two or more stones, which are held against the cylinder walls by spring pressure and rotated. The hone is usually driven by an electric drill of ½-inch or greater capacity.

39. Brake relining and drum truing equipment.—In the operation of automotive brakes a lining material exerts a frictional force against a drum, as illustrated in figure 120. To function properly, the brake linings must be in good condition, and their entire surface must come in contact with the drum. These linings become inefficient from wear; frequently the drums get out of round or acquire an irregular surface, and repairs to either or both are a common maintenance operation. The brake relining machine (fig. 121) and the brake drum truing machine (fig. 122) are power tools ordi-

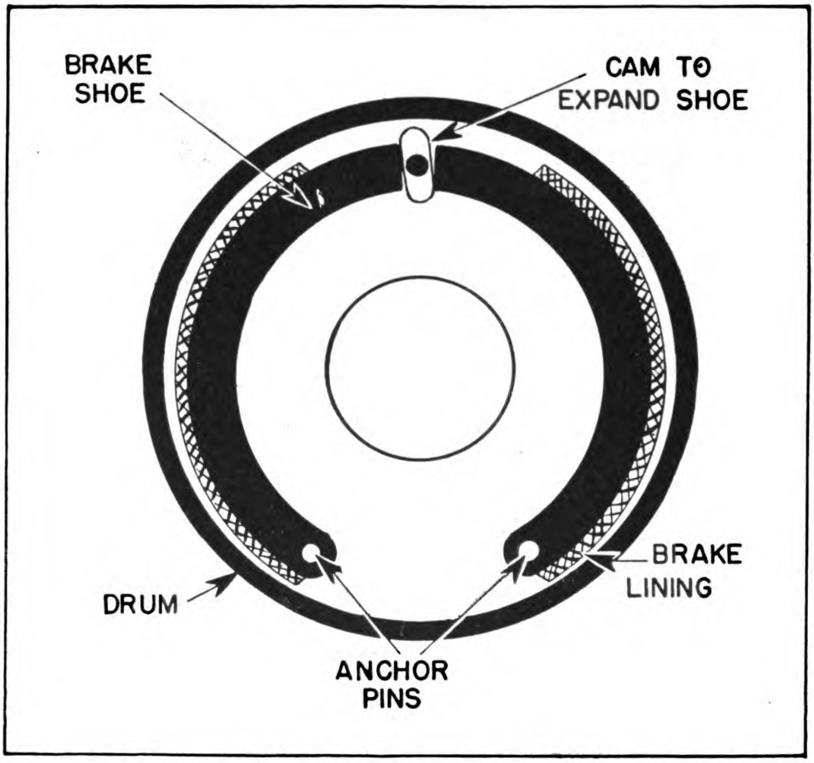

FIGURE 120.—Automotive brakes.

narily used to accomplish these operations. The brake relining machine is provided with attachments for drilling and countersinking the linings, and for removing the old rivets and driving the new ones. It also has an abrasive drum and guides for beveling the ends of the relined shoe, smoothing it, and grinding it to size. The drum truing machine is a type of lathe. By means of a cutting tool, it removes scores and resurfaces the drums round and true. The toolmarks it leaves are then removed by a grinding attachment provided with most types of brake drum lathes, or by means of a hone attachment secured to the tool post. Thus the greatest possible area of the lining comes in contact with the drums when the brakes are ap-

plied. For detailed instructions as to the use and care of either the brake relining machine or the drum truing machine, refer to instructions and service manuals which are issued by the various manufacturers.

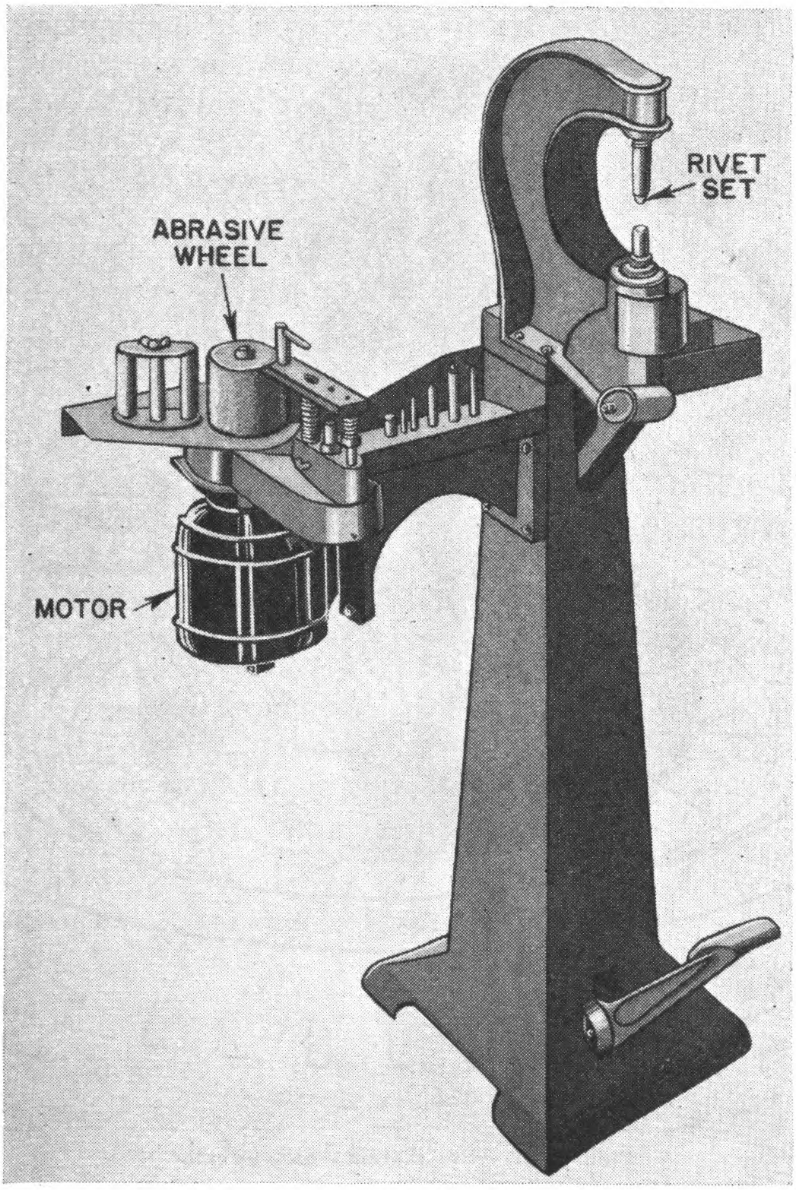

FIGURE 121.—Brake relining machine.

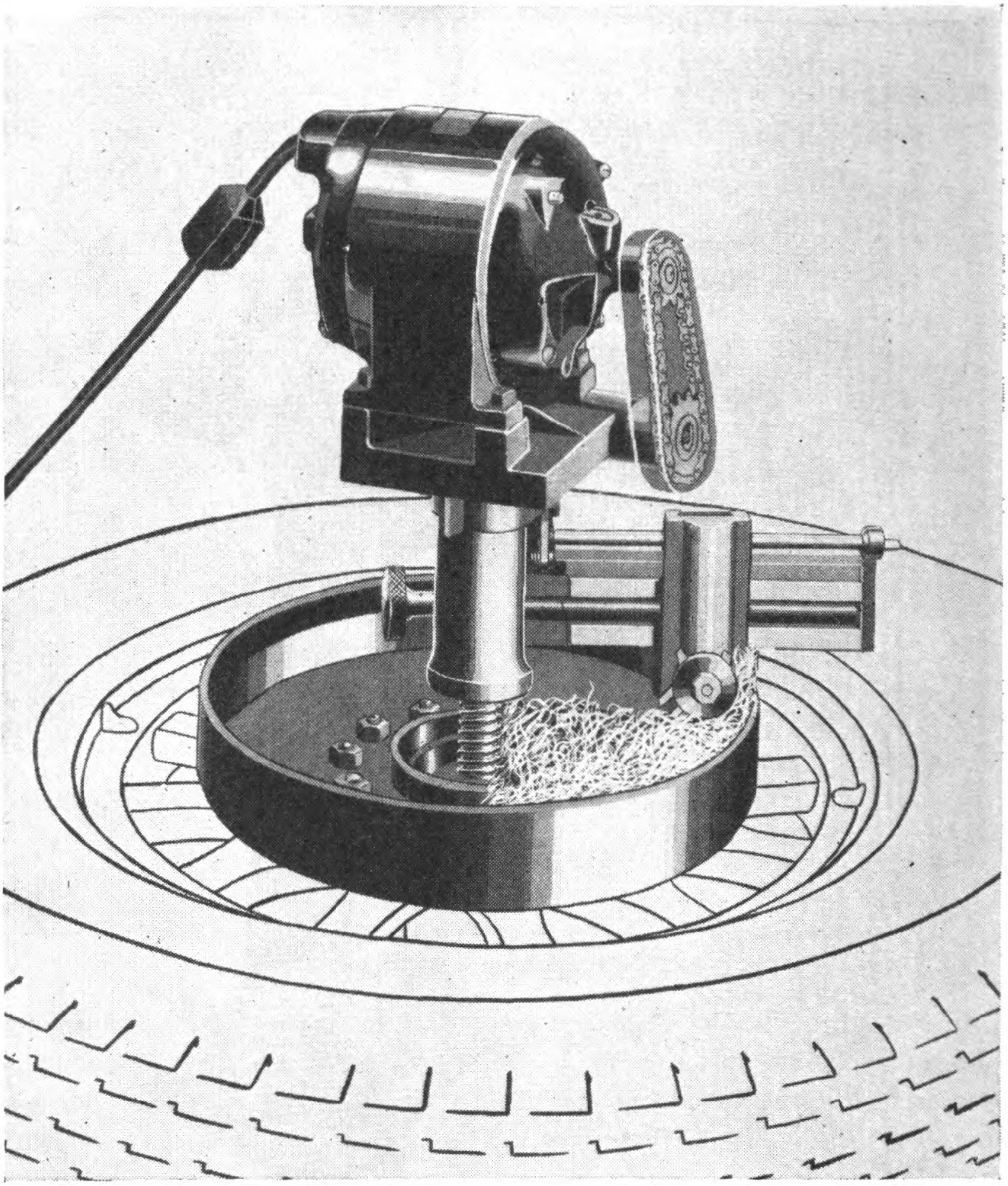

FIGURE 122.—Brake drum truing machine.

APPENDIX

LIST OF REFERENCES

The following sources have been consulted in the preparation of this manual for illustrations and text material. They contain more detailed information on hand, measuring, and power tools than is contained herein, and it is suggested that it would be advantageous for the student to consult them as collateral reading.

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